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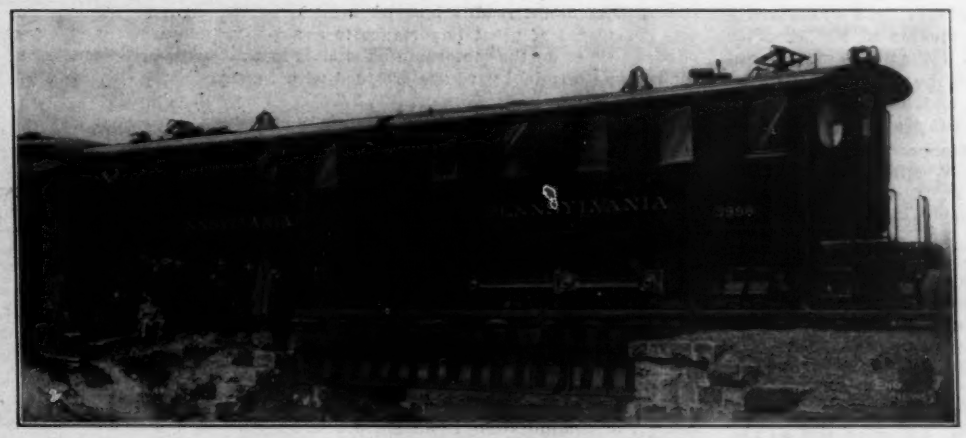
An Electric Locomotive Built on Steam Locomotive Lines: The Pennsylvania R. R. Type.

The first one of an initial order for 24 locomotives, for handling trains about the New York City terminal of the Pennsylvania R. R. has been completed and is being given a series of preliminary service runs on the tracks of the Long Island R. R., in order to develop any minor defects that may exist. The design is different from any other electric locomotive in service, and embodies steam-engine practice to a greater extent than any other. It is the result of several years of cooperation between the Pennsylvania R. R. and the Westinghouse Electric and Manufacturing Co. The development has been handled, on the part of the Pennsylvania R. R., by a locomotive committee composed of: Mr. Geo. Gibbs, Chief Engineer of Electric Traction and Station Construction, Pennsylvania Tunnel and Terminal Co. (Chairman); Mr. A. W. Gibbs, General Superintendent of Motive Power, P. R. R.; Mr. D. F. Crawford, General Superintendent of Motive Power, Pennsylvania Lines West of Pittsburg; Mr. A. S. Vogt, Mechanical Engineer, P. R. R.



SIDE VIEW OF THE PENNSYLVANIA DIRECT-CURRENT LOCOMOTIVE.

In wheel arrangement, weight distribution and general character of the running gear it is the practical equivalent of two American type steam locomotives coupled permanently back to back. The motors are mounted upon the frame and are side connected through jack shafts to driving wheels by a system of cranks and parallel connecting rods, similar to steam practice. The connecting rods are all rotating links between rotating elements, and thus can be perfectly counterbalanced for all speeds. The employment of such a scheme permits mounting the motors upon the frame, facilitates their spring support, and places the center of gravity at approximately that height above the rails, which has been found desirable in the best high-speed steam locomotives. In this case the center of gravity is approximately 72 ins. above the rails.

The same freedom of motion in the wheels and axles that is characteristic of the present steam locomotive is secured, but in these electric locomotives, the variable pressure of the unbalanced piston of the steam locomotive is replaced by the more constant torque and more constant rotating effort of the drive wheels, so that the pull upon the drawbar is thereby constant and uniform. It has been felt at first by some that, by this arrangement of driving, a return has been made to steam-locomotive practice as regards counterbalancing difficulties, but there are no unbalanced reciprocating weights involved; all weights are revolving ones and directly counterbalanced, so that as far as pounding upon the track is concerned, the effect is precisely the same as though the whole were driven without any pins or rods.

The requirements imposed on this design are severe and in a measure conflicting. The engine will be called upon to start a train of 550 tons trailing load upon the tunnel grades (approximately 2%), at the same time it is essential that speeds of 30 to 60 miles per hour can be reached with such a train at points between the Harrison, N. J., and the Sunnyside, L. I., yards. The guaranteed tractive effort is 60,000 lbs., but this is well within the capacity of the electrical equipment and the maximum useful effort is limited by the constancy of voltage of supply and the adhesion that can be secured. A normal speed of 60 mi. per hr., with full train load on a level track, is guaranteed, but this can be exceeded. The total weight of the locomotive is 332,100 lbs., of which 208,000 lbs. is on the eight drivers. The locomotive is claimed to develop 4,000 HP. for short times, say of 20 minutes, without abnormal temperature rise. For sustained heavy load, forced ventilation must be applied to the motors. At present this is not considered necessary. As seen from Fig. 3, this locomotive is articulated, each half carrying a single motor, four 68-in. drive wheels and one four-wheel, swing-bolster, swivel truck, with 36-in. wheels. Each section has its own steel cab the two cabs being connected by a standard Pullman vestibule.

All materials of the locomotive running gear were furnished under Pennsylvania R. R. standard specifications, with the exception that the axles, shafts, rods and crank pins are of special carbon steel, oil-tempered and annealed, and were subjected to special inspection.

From Fig. 2 it will be seen that the rigid wheel bases are 7 ft., 2 ins., and that the total wheel base of each half is 28 ft., 1 in. In what follows the more important feature of design are given.

FRAMES.—The locomotive frame proper, carrying the drive, is distinct from the cab frame carrying the auxiliary and control apparatus. The main frames are of cast steel of large cross section and massive construction and with an unusually large factor of safety.

The side frames are of sufficient strength to allow the engine to be raised, by jacks applied at fixed points provided in the construction, with all pedestal binders removed. The upper surfaces of the side frames are especially broad and furnish bases for the feet of the motor frames, which fit over the top members of the side frames with heavy flanges. (See Fig. 4.) There are five heavy cross ties between each pair of side frames and additional transverse strength is given by the motor frame. The five cross-ties are the bumper, articulation and jackshaft girders, the body bolster and the drive-wheel cross-tie. The bumper and the articulation girders are so proportioned that a bump equivalent to a static load of 500,000 lbs. (150,000 lbs. applied on center line of draft cylinder and 350,000 lbs. applied on center line of platform buffer) will produce no stress exceeding 12,000 lbs. per sq. in. in the frames.

The jackshaft girder is of inverted U section and gives rigid support to the jackshaft bearing braces. It also carries, upon facings, the driver-brake cylinder, while the brake-lever fulcrum is integral with the girder.

The cross-tie between the driving wheels is of diagonal form, especially fitted for stiffening the bottom members, and also providing a base for the front driver-brake hanger pin. This tie fits between the upper and lower members of the side frames and assists in rigidly supporting the heel of the motor frame.

The articulation girder is designed to be rigid diagonally in the horizontal plane and to accommodate the articulation coupiings. The body bolster carries the swivel-truck center pin.

WHEELS.—The 68-in. drive wheels have cast steel centers, 3-in. rolled steel tires, and are fitted with retaining rings. The centers are counterbalanced for the crank pins, but the counterbalances are offset from direct opposition to correct for transverse unbalance. The crank pins are set quartering. The truck 36-in. wheels are of rolled steel.

AXLES, CRANKS, ETC.—The axles, jackshafts and motor shafts are of special carbon steel, oil-tempered and annealed. They are of large diameter, finished all over and each has an axial hole throughout. The motor-shaft cranks are forged with integral counter-balances, and are accurately

located in quartering positions, press-fitted and keyed to the shaft. The jackshaft cranks are forged integrally with the shaft in quartering position. Their counter-balances are keyed in position. As with the driving wheels, the counter-balances of motor shafts and jackshafts are offset from direct opposition to the cranks in order to complete the balance. All crank pins are also of the special carbon steel, oil-tempered and annealed, are bored axially and press-fitted to their respective cranks and wheels. All the connecting rods are also of special carbon steel, oil-tempered and annealed. Inasmuch as the action of the brake shoes, the wear of the axle and the take-up of the wedges in the pedestal tend to decrease the distance between the axle and the jackshaft, the main rod is adjustable at each end, so fitted that all take-up shortens the rod and furnishes compensation. The type of adjustable head is that employed on Class E-3 locomotives of the Pennsylvania R. R. All other rods are fitted with solid bushed ends. The main journals are like those on the Class E-3 P. R. R. engines. The jackshaft and motor bearings are fitted for oil and waste lubrication.

DRAFT GEAR.—The bumper ends of the locomotive are fitted with Westinghouse friction-draft gear, standard M. C. B. couplers and platform buffers of the Pennsylvania R. R. standard design.

The articulation ends are fitted with permanent couplings of long twin draw bars and Westinghouse friction-draft gears. The leading half serves as a leading truck and the other half as a trailer in whichever direction the locomotive may be moving. This coupling gear is designed to oppose any possible "nosing" tendency or buckling action of the halves, and so that the leading half will guide the following and so relieve the rails and flanges to a considerable extent.

SUSPENSION.—The frame is supported on the axle journals by spring rigging, equalizing bars, semi-elliptic springs, etc., as in standard three-point steam-locomotive suspension.

CABS.—The cab of each half is an independent structure complete in itself so constructed that it may be lifted bodily from the running gear, with its floor and all auxiliary apparatus, and set upon any convenient flat surface or trestle support without damage, leaving the motor and running gear accessible for any desired overhauling and permitting attention to be given at the same time to the machinery in the cab. The cabs are identical in construction and fittings, and so arranged that they are interchangeable.

The location of the cabs in assembling is determined by dowels fitting in corresponding holes in the running gear. They are held in place by a number of bolts sufficient for security, but the running gears would have to tilt beyond their limits of stability before the cabs would leave their seats. Bulkheads and doors are so arranged that the motor and air compressor compartments, containing nearly all of the auxiliary apparatus, may remain lighted at all times with no intrusion of light in the controller compartment to affect the vision of the engine driver. Provision is to be made for heating the cabs with steam furnished from electric steam generators in the cabs. These generators will also supply steam to the cars after their disconnection from the steam locomotives, at Harrison, N. J.

CAB DETAILS.—Each cab is fitted with a hand-rung bell, a chime whistle (blown by air), sand box and sanders, and a small overhead pantagraph collector for the power supply at yard gaps in the third rail system. The sanders and overhead collectors are operated by pedal switches near the master controller and close by the driver's seat.

Each cab carries on its own roof, at the end, a headlight with a 50 c.-p., incandescent, electric, stereopticon lamp operated at 240 volts, from the main current, with suitable resistances. These headlights are not intended to be searchlights, although they might readily have been made so. It was considered of great importance to avoid any blinding effect on the motorman as signals in the tunnels and terminal yard are provided with color indication only.

ELECTRICAL EQUIPMENT.—As briefly stated before, the motive power of the locomotive lies in two motors of a 600-volt, 2,000-HP., commutating-pole type. Each motor weighs complete without its crank, 42,000 lbs. The 2,000-HP. is developed with a current of 2,900 amperes at 600 volts.

The general appearance of the motors is shown in Fig. 4. They are free from the usual space limitations imposed on railway motors, and the designers have been free to secure all possible advantages of this. The motors at present are run open in the cab where bearings, windings and commutator are accessible for constant inspection. The commutation is so perfect under all conditions that it is not apparent to the observer that any current is flowing from the brushes. There is a great deal of natural induced ventilation, but, if needed, forced ventilation apparatus can be attached.

Fig. 4 shows how the motor field frame is built to permit fastening to the locomotive side frame. In addition to being bolted the feet are wedged in place.

There are ten main and ten commutating-field poles. The main-field winding is in two sections, both of which are used together at low-speed operation. At high speeds only one-half is needed, and at intermediate control points one is shunted with resistance. These field positions are available for all series, and parallel groupings of the motors, so that eight running positions (or speeds) are possible. "Bridging" connections, of course, are used in passing from series to parallel groupings of the motors, so that the main circuits are not opened in the process.

While it is not intended to operate singly the halves of this locomotive, yet the connections and control are such that the train may be operated under reduced power by one motor and in this case the resistances of both halves are used. The grids are designed safely to carry the heavy currents of such an event. Under such circumstances the locomotive will exert a tractive effort of 25,000 lbs., which is close to the point at which the drivers will slip.

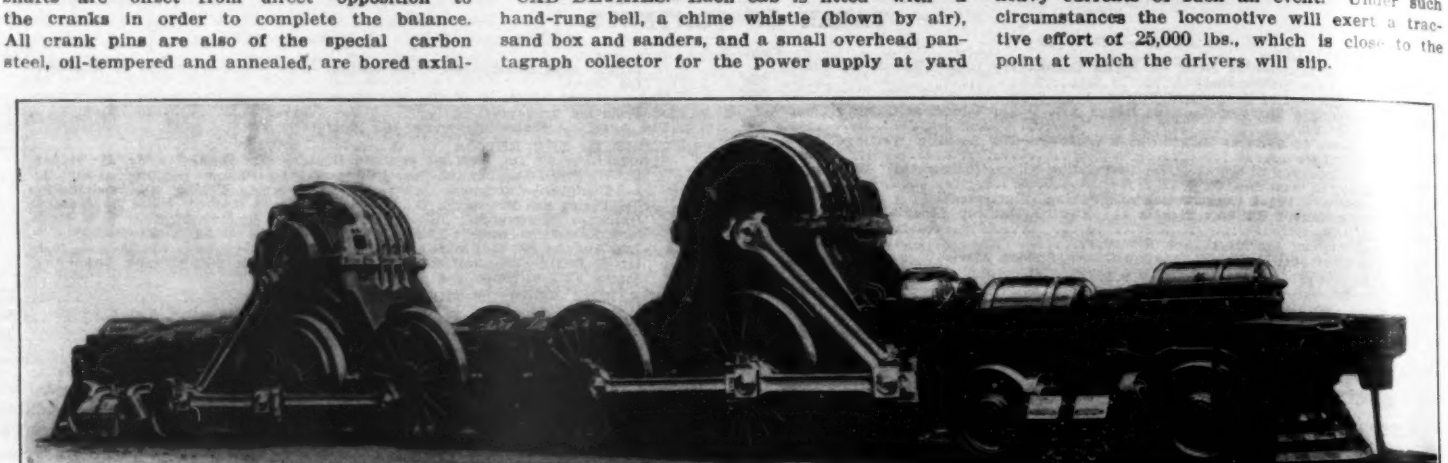


FIG. 2. RUNNING GEAR OF THE PENNSYLVANIA ELECTRIC LOCOMOTIVE.

The motor connections are changed by electro-pneumatic switches, actuated by compressed air from the air-brake compressor, and controlled with low-voltage current from the master controller. Suitable train-line receptacles and jumper cables are provided, for the locomotive ends, so that two or more locomotives may be operated as one. The low-voltage control is supplied by a small storage battery in each half of the locomotive. These are automatically charged by shunting part of the current of the air-compressor motors.

To relieve the drive in case of too sudden braking of the drive wheels, the motor-armature spider is held on the shaft by an adjustable friction fastening.

A pair of over-running third-rail shoes is mounted on a hard-wood beam on each side of the swivel trucks. These collectors are shown by Fig. 3.

AIR-BRAKES.—Each half of the locomotive is equipped with complete Westinghouse air-brake equipment of regular railroad type, except that the air is supplied by a motor-driven two-stage compressor, having a displacement of 65 cu. ft. of free air.

The brake rigging on this locomotive is proportioned for the weights of the parts braked and for the delivery of 85% braking power at 50 lbs. per sq. in. cylinder pressure.

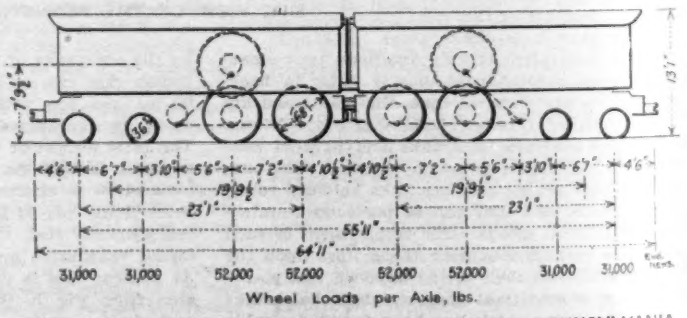


FIG. 3. MAIN DIMENSIONS AND WHEEL LOADS. PENNSYLVANIA ELECTRIC LOCOMOTIVE.

The running gear and mechanical parts of this locomotive were built by the Pennsylvania Railroad at their Juniata shops in Altoona, Pa. The air-brake equipment was built by the Westinghouse Air Brake Company, and the electrical equipment was built and the apparatus was assembled by the Westinghouse Electric and Manufacturing Company at their East Pittsburg works.

The Development of Centrifugal Pumps.*

By J. D. BERG,† M. E.

Any device which has had a substantial development and constantly increasing use over a period of years, must have some features about it which recommend its use. These excuses for the existence of centrifugal pumps consist of its several advantages over other types.

In the first place, a centrifugal pump is very simple in construction, consisting fundamentally of a shaft, two bearings, and one or more impellers mounted on the shaft. This, with the flexible couplings and driving apparatus makes up the complete machine. The first cost of installation, not only of the machine itself but of the foundations and buildings necessary is always considerably less than for other pumping machinery of the same economy. The absence of large-sized packing and of the necessity of frequent packing, the small cost for lubrication, the small cost of repairs, a minimum cost for attendance, all these considerations, while they may not necessarily mean that the centrifugal type of pump is the one to install in all cases, are sufficient to warrant a full investigation of this type before any installation is made.

In the early days, before the introduction of a high-speed, economical drive, the use of centrifugal pumps was restricted to conditions of low lift, say from 10 to 60 ft. Inasmuch as in water-works for towns and mills, heads varying from 100 to 700 ft. must be produced, it can easily be seen why the centrifugal pump was not then a matter of interest to water-works and mill engineers except in cases of low lift, filtration or condenser work. However, with the introduction of the steam turbine and reliable, high speed motors, this condition has ceased to exist.

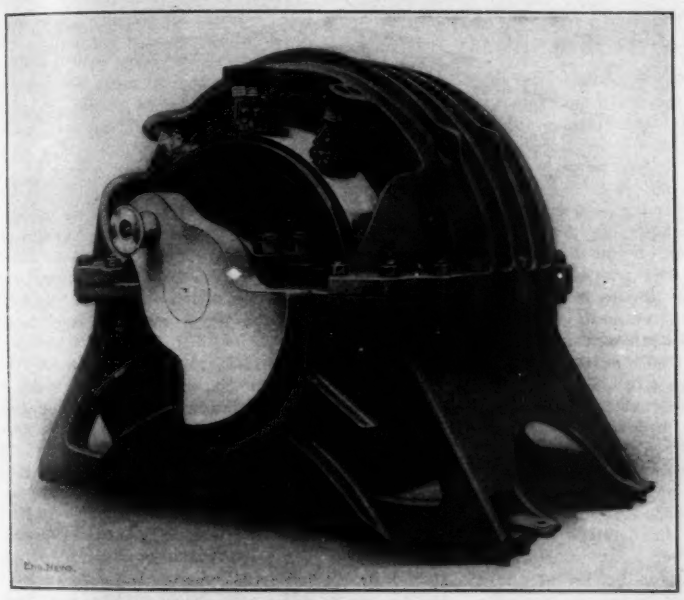


FIG. 4. THE 600-VOLT, 2,000-HP. DIRECT-CURRENT MOTOR OF THE PENNSYLVANIA LOCOMOTIVE.

A consideration of the result of the development of centrifugal pumps, might be considered more interesting than the history of this development.

With the ordinary old open type of impeller, efficiencies of from 55 to 35% and sometimes as low as 20% were obtained. This was natural as practically no attention was paid to correct design, and one shape of impeller vane was made to work under a great variety of conditions. It was also not very important to attempt to get higher efficiencies as these pumps were usually of small capacity against low head, and 5 or 10% better efficiency did not mean a great saving in the power requirements. However, as larger quantities had to be handled against greater heads, then the 5 or 10% or even 1 or 2% better efficiency considerably affected the annual coal bill and it became necessary to look closer to proper design.

The requirements to be met by all pumping machinery, in these later years, have become more exacting as the questions of efficiency and cost of operation have been investigated. Formerly, if a manufacturer were asked for a pump to have a capacity of 3,000,000 gals. of water against a head of 60 ft., and he had a pump which was designed for a capacity of 3,000,000 gals. per day against 45 ft., very likely the same pump would be used and the speed increased if possible, to obtain the higher head. This naturally meant that the efficiency obtainable at the higher head was not as high as with a pump designed to suit the conditions. There was also the consideration that when the pump was installed, it would likely be found that the head was either 50 or 70 ft., which would still further work against the pump efficiency.

These facts are recognized by pump manufacturers to-day and means are taken for the elimination of former troubles. The leading manufacturers now do not merely take the word of the man who is going to install the pump that his pressure is a certain amount, but study the conditions thoroughly before submitting a proposition. Furthermore, after the conditions have been gone into thoroughly, a design is worked out by the engineering department, with the result that in the majority of cases, an entirely new impeller is laid out for these particular conditions, and in some cases even a new casing is needed to suit them.

It is understood of course that a centrifugal pump adds energy to the water by increasing its velocity, which velocity energy is afterwards transformed into pressure energy. The peripheral velocity of the impeller determines the pressure which can be produced. The peripheral velocity can be increased either by increasing the diameter of the impeller, or by increasing the speed. The limit of the diameter of an impeller is soon reached on account of the longer water passages which produce excessive friction and decrease the efficiency. The problem therefore, ordinarily reduces to one of increasing the revolutions per minute. This was done at first by belt driving the pump, but the troubles incident to belt drive retarded the natural development of the centrifugal pump. Direct connection is preferable and as stated before, the steam turbine and high speed motor, supplied that which was necessary to give its development the proper impetus.

Compounding pumps, mounting more than one impeller on the same shaft, with water passages arranged for discharging from one impeller to the suction opening of the next impeller, together with the possibility of obtaining high speed, have made it possible to obtain any pressure with a centrifugal pump that can be obtained with other types.

This is not all that is necessary, however. The question of doing this efficiently is the important one. If it were possible merely by mathematical calculation, to determine the proper design of a centrifugal pump for maximum efficiency, their use would be much more general than is now the case. In no problem of engineering, except possibly that of producing air pressure by means of a centrifugal blower, do experiments and tests play such an important part. Mathematical calculations from the result of experiments are important, but without the tests a designer is completely at sea. But, a first-class pump manufacturer, having the result of a great number of tests on his designs, can develop pumps for new conditions with great accuracy.

As an example of the development of centrifugal pump design, and ability to use empirical formulæ intelligently, it might be stated that it is now not only possible to get a guarantee of efficiency together with one of capacity at a certain definite head, for centrifugal pumps, but it is also possible to determine, before the pump is built, what the shape of its curve of characteristic performance will be, i. e., how the capacity will vary with varying heads at constant speed or at varying speed. This is an important advancement, as pumps, especially on city work, usually do not work at a constant pressure, and it is often desirable to know what the capacity will be at say, 10 or 15% increased or decreased pressure.

It is also possible to get any shape of characteristic which might be desirable. In some cases the water is pumped into the bottom of a stand-pipe. This means that when an extraordinary demand for water is placed on the system, the level of the water will fall. It is at this time that it is desirable that the pumps discharge as much water as possible, and at constant speed a centrifugal pump will actually discharge more water at decreased heads. This makes the stand-pipe as an automatic governor on the system. The centrifugal pump has been developed to the point that the designer can predetermine almost exactly what capacity will be discharged at varying heads. It can be definitely guaranteed that the driving apparatus will not be overloaded, regardless of whether the discharge head is increased or decreased. This is one of the most important developments that have been made in pump design, as the old type of pump and, in fact, most pumps being manufactured to-day will overload the driving apparatus, some on the head being increased, and some on its being decreased from the normal point.

It can easily be shown that for stand-pipe service, a characteristic curve having a shut-off pressure considerably higher than the working pressure should be used. This in order to take advantage to the fullest extent of that ability of the centrifugal pump to discharge an increased capacity of water against a decreased head.

Again, when the water is pumped directly into the main, it is desirable to have as flat a characteristic curve as possible in order that when the demand is not great, the pressure will not run up dangerously. When the attempt was first made to obtain this type of characteristic curve, great trouble was experienced from the fact mentioned above, that is, on decreased heads the driving apparatus would be overloaded. This point has been so thoroughly investigated and experimented upon by several pump manufacturers that now with a pump having say a capacity of 3,000,000 gals. of water per day against 150 lbs. pressure, if the discharge line should be broken right at the pump, the power required to drive the pump under these conditions would be less than that required at 150 lbs. pressure. These problems, while they may be considered trivial to the ordinary investigator, are the ones which have taken longer for solution than might be supposed would be necessary, and the solution of which has done much toward the commercial adaptation of centrifugal pumps to all classes of work.

The details of construction have been improved remarkably as centrifugal pumps have come into more general use. On almost all first-class pumps, bronze instead of cast-iron impellers are now used. All points at which there is a possibility of wear are protected by small removable parts which makes the up-keep small. The present day centrifugal pump is built for hard, rough service, being made much heavier and more substantial than formerly. This development was mainly the result of using the pump for mill service, which is conceded to be as severe as there is. Demands of this service have made the interior working parts more accessible for quick repairs. The separation of the bearings from the case, splitting the bearings, and the glands, etc., while possibly peculiar to only a few pump manufacturers, mark a development in centrifugal pumps which has done much to reduce the operating cost and so has increased its popularity.

It can safely be stated that a centrifugal pump, either motor or turbine driven, can be used on any service where direct-acting pumps are used. This statement is not meant to imply that it is always advisable to install centrifugal pumps, as there are some conditions which can be met better by direct-acting pumps. However, it would seem that a prospective purchaser should approach the subject with the idea of investigating all types, and then decide after he has compared all the data, which type suits his conditions better. It may be that for one set of conditions, a direct-acting steam pump is preferable, while under other conditions a motor-driven centrifugal pump may be preferable.

To show what widely varying conditions can be met successfully by centrifugal pumps, and the extent to which these pumps have been adopted by industrial concerns, the partial record of installations in one of the large cities of the United States might be considered with profit. At three of the larger manufacturing plants alone in this city, there are installed two pumps having a total capacity of 14,000,000 gals. of water per day against a total head of 20 ft.; one pump having a capacity of a little over 9,000,000 gals. per day against a total head of 37 ft.; one pump having a capacity of 9,000,000 gals. against a total head of 60 ft.; one pump having a capacity of 40,000,000 gals. against a total head of 46 ft.; one pump having a capacity of either 40,000,000 gals. against a total head of 46 ft. or 16,500,000 gals. against a total head of 120 ft.; three pumps having a combined capacity of 31,500,000 gals. of water per day against a total head of 120 ft.; one pump having a capacity of 18,000,000 gals. against a total head of 106 ft.; one pump having a capacity of 15,000,000 gals. of water per day against a total head of 126 ft.; two pumps having a combined capacity of 20,000,000 gals. of water per day against a total head of 80 ft.; two pumps having a combined capacity of 12,000,000 gals. of water per day against a total head of 110 ft.

We understand that one pump manufacturer is at the present time building a pump to have a capacity of 1,000,000 gals. of water per day against a total head of 1,400 ft.

In one industrial plant in Ohio, there are installed the following pumps: One 20,000,000-gal. 40-ft. pump; three pumps having a combined capacity of 30,000,000 gals. against a head of 50 ft.; and four having a combined capacity of 52,500,000 gals. against 120 ft. We understand that one of these pumps ran for over seven months, being shut down in that time only once for 20 minutes.

A town in southern Kentucky has an interesting installation of turbine-driven centrifugal pumps. It consists of two 110-HP. and one 300-HP. machines. One of the smaller machines supplies the sedimentation basins with raw water from the Ohio River. The other 110-HP. machine supplies 4,000,000 gals. of water per day against

*From a paper presented at the Convention of the Central States Water Works Association, Columbus, Ohio, Sept. 28.

†Vice-President, Dravo-Doyle Co., Engineers, Lewis Block, Pittsburg.

a total head of 115 ft., for domestic service. This pump is also arranged for supplying 2,000,000 gals. of water per day against a total head of 231 ft., for fire service. The 300-HP. machine supplies 6,000,000 gals. against a total head of 231 ft. for fire service, which gives a total fire capacity of 8,000,000 gals. of water per day against 100 lbs. pressure. The 300-HP. machine is also run on domestic service at times, under which condition it is run at a lower speed. The duty of the larger machine on domestic service, low speed, is almost the same as that of the 110-HP. machine, which makes it an excellent spare for the system.

A city in Indiana has a power canal with approximately 28-ft. head available. Formerly, part of the water for this city was pumped by means of direct acting pumps, geared to water motors. About 18 months ago a four-stage 12-in., centrifugal pump was installed. This pump was direct connected to a pair of water turbines, running at speeds varying from 350 to 550 r. p. m. The pump is required to work against either 200 or 300 ft. head, the lower pressure being for domestic service, and the higher pressure for fire service. The installation we understand proved so satisfactory that they are now installing an additional machine, and are having a third machine built to be an exact duplicate of the other two.

A city in Virginia has installed four 4,000,000-gal. pumps, to work against a total head of 168 ft. Each of these pumps is direct connected to a 200-HP. alternating current induction motor, running at a speed of 885 r. p. m. Under these conditions, which ordinarily would not be considered good for a centrifugal pump at all, an efficiency considerably better than 70% was obtained on test. These pumps have not been running a year, and it will be interesting to ascertain the cost for attendance and up-keep.

Besides the installations mentioned above, a great number of installations for fire service have been made in the last year or so. Notable among these installations are the ones at New York and Chicago, the reports of which have been satisfactory in the main.

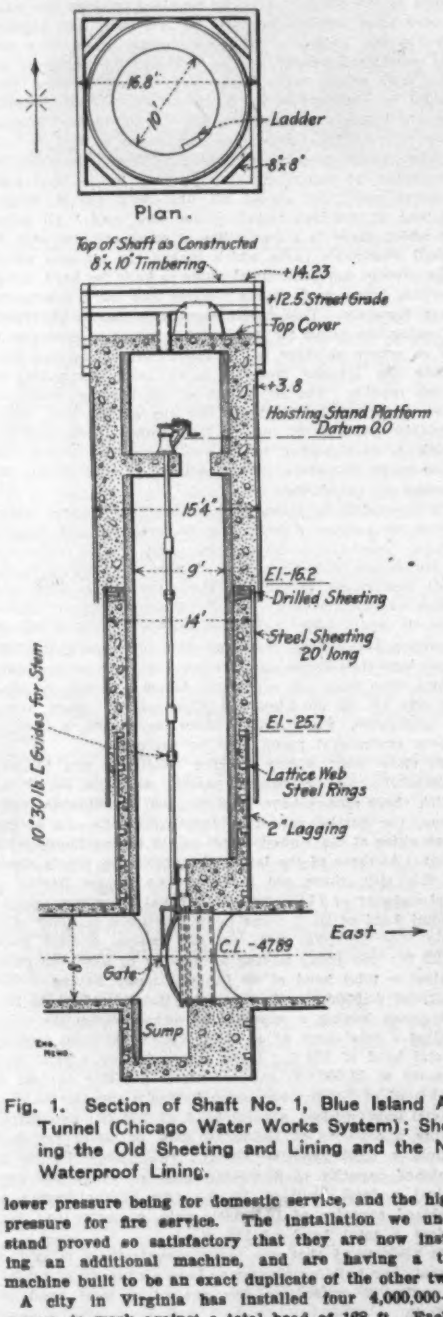


Fig. 1. Section of Shaft No. 1, Blue Island Ave. Tunnel (Chicago Water Works System); Showing the Old Sheeting and Lining and the New Waterproof Lining.

One field where motor-driven centrifugal pumps have been used to good advantage in town water-works is that of booster service for outlying districts. There have been several installations made of this character and they have proven very successful. In one case which has been brought to our attention, two pumps were installed, each having a capacity of 1,000,000 gals. per day against a total head of 88 ft. It will be understood of course, that regardless of the pressure which exists on the suction side of these pumps, they add 88 ft. to this pressure. As they are driven by alternating-current induction motors, the operation of which is very simple, and as there are only ring-oiled bearings on the entire apparatus, they require a minimum amount of attention and are really the most satisfactory pumps which could be installed for this service. It would seem there is a large field for the use of these pumps for producing fire pressure in outlying districts, where, on account of excessive friction in existing lines, it is necessary to raise the pressure at the main station a great deal higher than would be necessary if the lines were of the proper size. A plan, which has been suggested in some cases, is to install several of these pumps in outlying districts and so arrange them that when only domestic service is required in the district the water will be by-passed around the pump. A check valve opening in the direction of flow would be installed in the by-pass and another between the pump discharge and the line. Upon an alarm of fire being sent in, the motor can be started from the main station, and on account of the greater pressure on the discharge side of the pump, the check valve in the by-pass will be closed and the pressure boosted the proper amount.

Waterproofing a Shaft of the Blue Island Ave. Water Tunnel at Chicago.

In the construction of concrete lining for tunnels and shafts one of the important points is to make the lining watertight, and in cases where the leakage through the finished lining is excessive it is usually a difficult matter to remedy this condition. An interesting and instructive piece of work of this kind has been carried out recently in one of the shafts of the Blue Island Ave. tunnel, at Chicago. The tunnel is one of the important recent improvements in the water supply system of Chicago, extending from a point near the lake shore (north of the river) to a pumping station 800 ft. south of the intersection of 22d St. and Ashland Ave. The tunnel is 8 ft. diameter inside the concrete lining, and has a length of about five miles. It was built by contract during 1907-1908, and was described and illustrated in our issue of Oct. 22, 1908.

There were eleven shafts on the line of the tunnel, of which seven were permanent shafts and four were temporary working shafts. Of the former, five are fitted with sluice gates, enabling the flow of water in the tunnel to be shut off or diverted.

Shaft No. 1 is one of the permanent shafts, and is located in Delaware Place, about 200 ft. east of Lincoln Park Boulevard, and not far from the lake shore. It is located in a tract of waste land, the title to which has been under litigation for several years. The land has been used by the city as a dumping ground for garbage, street sweepings and refuse, and clay from tunnel excavations; private companies also used it as a place for disposing of refuse. Thus for a depth of 12 or 14 ft. the shaft was in made ground, composed largely of decaying vegetable and animal matter. Below this, it passed through 18 to 25 ft. of sand overlying the blue clay in which the tunnel was driven. Work was commenced in June, 1907.

The method of sinking must be described, in relation to the subsequent work of waterproofing. A ring of interlocking steel sheeting 15 ft. 4 ins. diameter and 20 ft. deep was first put down by means of a pile driver and water jet. A pit with square sets had been sunk about 8 ft. before this sheeting was driven, and the lower end of the sheeting thus penetrated the clay. The water jet washed this clay from below the sheeting, so that the water was allowed to flow down the outside and up the inside of the sheeting. The excavation was then carried down to about 5 ft. from the bottom of the first ring of sheeting and a second ring, 14 ft. diameter and 20 ft. deep, was then driven inside of and as close as possible to the first ring. Below this second ring, 2-in. vertical lagging was used, braced against the clay by interior latticed steel rings. The arrangement of the sheeting and lining is shown in Fig. 1. The shaft was sunk to 58 ft. below Chicago datum, or a depth of about 71 ft.

The interlocking sheeting was apparently watertight, but at the level where the inner and outer sets lapped, there was considerable leakage. An attempt was made to grout the space between the rings while the water was flowing, but this proved unsuccessful, and after spending some time over the attempt the concrete lining was started at the bottom of the shaft. This lining varied from 8 to 24 ins. in thickness, and was composed of a 1:3:6 mixture, although it is generally considered that this is too lean a mixture to be watertight, especially under pressure. It is stated that no precautions were taken to protect the fresh concrete from the water pouring down the shaft, and that as a result much of the cement was washed out. After the lining was completed and the forms had been removed, there were numerous leaks in the concrete, the flow aggregating about 60 gals. per minute. An effort was made to plaster the lining with a quick-setting cement, but this proved unsuccessful. After some six months work, the attempts to make the shaft watertight were abandoned, and after completing the tunnel drifts starting from this shaft, it was closed with a temporary cover. This was in April, 1909.

The water leaking into the shaft had seeped through the "made ground," which consisted of refuse from cold storage warehouses and of garbage and refuse dumped by the city, as noted above. The water carried a large amount of soluble organic matter, and this collected on the surface of the concrete in the form of a slimy brown deposit which gave off an offensive odor. It was imperative that the seepage water should be excluded, to prevent possible pollution of the city's water supply. There was no question as to the strength of the shaft, in view of its heavy concrete lining and of the outside shell of interlocked steel sheet piling. The only trouble was the exclusion of water which entered at the level where the upper and lower rings of steel lining overlapped.

In the spring of 1909, the city awarded to the Empire Construction Co., of Chicago, a contract to build tunnels connecting the Blue Island Ave. tunnel with the 22d St. and Chicago Ave. pumping stations, and to set a 96-in. circular sluice gate on the east side of shaft No. 1 of the Blue Island Ave. tunnel. At that time, it required a No. 7 Cameron pump running continuously night and day to take care of the seepage in the shaft. The attention of the city officials was directed to the condition of the shaft and the necessity of preventing the seepage, and it was finally decided to award to the company a contract for making the shaft watertight. The plan for effecting this was suggested by Mr. C. C. Saner, Chief Engineer of the company, and was approved by the city's engineers. It was carried out under the direct supervision of Mr. L. E. Alswede, Superintendent of Construction for the company.

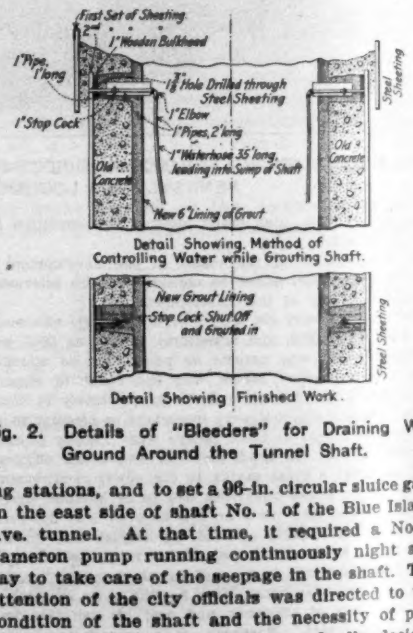

First Set of Sheeting
1" Wooden Bulkhead
1" Pipe, 1' long
1" Hole Drilled through Steel Sheeting
Steel Sheeting
1" Stop Cock
1" Elbow
1" Pipes, 2' long
1" Waterhose 35' long, leading into Sump of Shaft
Old Concrete
New 6" Lining of Grout
Detail Showing Method of Controlling Water while Grouting Shaft.
New Grout Lining
Stop Cock Shut Off and Grouted in
Steel Sheeting
Detail Showing Finished Work.

Fig. 2. Details of "Bleeders" for Draining Wet Ground Around the Tunnel Shaft.

The first step was to make the walls of the shaft dry, or at least free from running water. No water came through that part enclosed by the lower 20 ft. of sheeting, and here a watertight

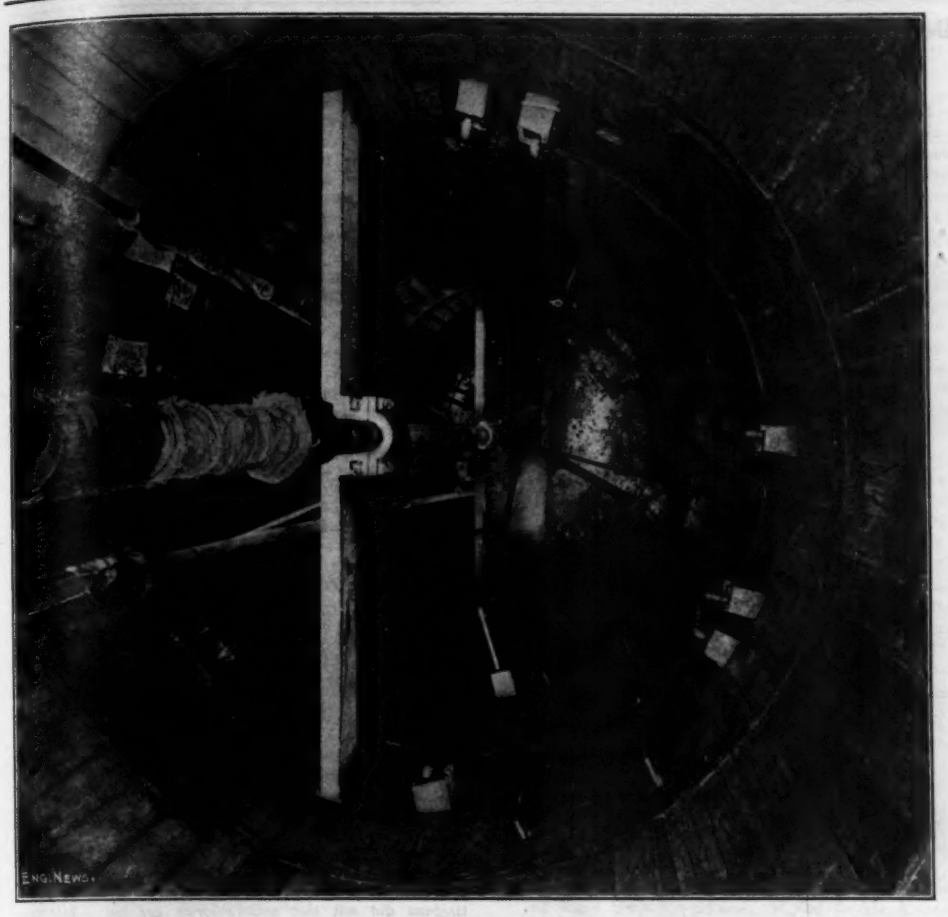


FIG. 3. INTERIOR OF SHAFT NO. 1, BLUE ISLAND AVE. TUNNEL, WITH "BLEEDERS" AND HOSE PIPES IN PLACE.

ring or gutter 10 ft. diameter was placed around the wall of the shaft. A down-spout carried the water collected by this gutter into the sump of the shaft, while the waterproof lining was built in this part of the shaft. This consisted of a 6-in. lining of cement grout, as described more fully below.

It was found that most of the water came through the concrete at the elevation where the upper and lower rings of steel sheeting overlapped. Here the concrete was cut away sufficiently to expose the face of the lower (and inner) sheeting. Holes 1⅜-in. diameter were drilled through this sheeting, and water flowed freely from most of these holes. In each hole was inserted a 1-in. pipe 12 ins. long, and on this was fitted a 1-in. stop-cock (with the valve open); to this was attached a 2-ft. piece of pipe, with an elbow and another 2-ft. piece of pipe, the latter hanging vertically in the shaft. All the pipe was of 1-in. size, and to the end of the vertical pipe was attached a 35-ft. length of 1-in. rubber hose leading into the sump. A bulkhead of 1-in. plank was fitted at the back of the hole, and a box 6 × 4 ins., about 2 ft. long, was placed in the hole, enclosing the pipe and valve. The space outside of this box (between the box and the old concrete and sheeting) was then filled carefully with cement grout. The arrangement of the piping and boxes is shown in Fig. 2.

The first plan was to lead a short piece of hose into a vertical open pipe. The long hose pipes, however, caused a suction (as noted below) and were easily shifted out of the way of work in the shaft.

The flow of the water through the long hose pipes created a suction which tended to promote the flow and so drain the water from the ground adjacent to the shaft. There were 13 of these "bleeders" around the shaft at this elevation, and it was found that after thus relieving the pressure on the wall most of the smaller leaks stopped running. At a lower level, eight additional "bleeders" were put in, although it was considered by the engineer that these would not have been necessary, if a sufficient number had been placed around the circumference of the shaft at the higher elevation. With these drains all completed, the surface of the concrete lining was mainly free from running water, the water being carried to the sump by the lines of ¼-in. hose. There were, however, a number of fine capillary holes in the concrete through which water flowed, but these were dealt with by the use of a dry grout as noted below.

The wall of the shaft was then thoroughly washed and scoured with wire brushes, and the surface roughened with picks. This latter was found to be easy work, owing to the condition of the concrete due to water falling upon it while under construction, as noted above. The surface was then given a wash of neat cement.

The permanent waterproof lining was then commenced. This consisted of 6 ins. of cement grout, giving the shaft a finished inside diameter of 9 ft. The grout was composed of 1 part Portland cement and 2 parts of sharp torpedo sand, made stiff, but of such consistency that water would flush to the top in tamping. Where the capillary holes were encountered, the grout was made very dry so as to absorb the water weeping through these holes and thus prevent it from weakening the grout.

The wooden forms were 8 ft. 8 ins. diameter, set 4 ft. apart. The lagging was of 2-in. vertical planks, beveled and planed, and in 4 ft. lengths to permit of thorough tamping. Wherever knot holes or crevices appeared, the forms were plastered with clay to prevent any escape of the water from the grout.

A concrete mixer of the drum type was brought on the work, as the contractor was of the opinion that a more uniform quality of grout could be made by machine than by hand mixing. The city's engineer in charge (Mr. Wm. D. Barber, M. Am. Soc. C. E.) insisted, however, that the grout should be mixed by hand, on the ground that an intimate mixture of sand and cement alone cannot be made in a mixing machine with fixed vanes or blades. For concrete, with stone or gravel, the conditions are different, as the stones assist in agitating and mixing the material. The method, as carried out under the direction of Mr. Barber, was to mix the dry sand and cement thoroughly in a mortar box, and then to add the water gradually, and continue mixing until the necessary consistency was reached.

The grout was lowered in buckets holding 2½ cu. ft., and dumped upon a platform, from which

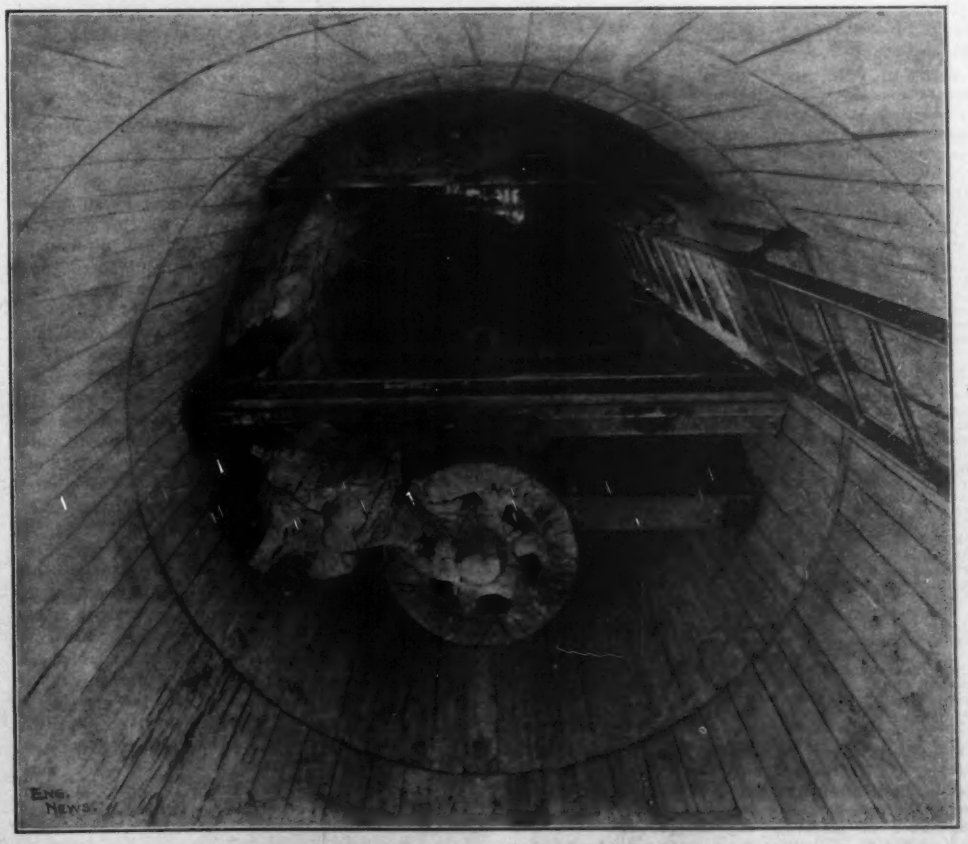


FIG. 4. INTERIOR OF SHAFT NO. 1, BLUE ISLAND AVE. TUNNEL, WITH "BLEEDERS" REMOVED AND NEW LINING COMPLETED.

it was shoveled into the forms. When in place it was tamped or puddled with tools similar to the hoes used in removing ice from sidewalks. With these tools the grout was spaded thoroughly against the back of the lagging, in order to eliminate all air bubbles. For commencing the work each day, the surface of the previously-laid grout was drained of any water that remained on the top, and carefully cleaned. It was then dressed with a grout of neat cement to make an effective bond of the old and new work.

After the lining had been completed to the top of the shaft, and the grout had been allowed to set for a sufficient time, the forms and lagging were removed. The hose and pipes were removed, unscrewing the horizontal pipe from the stop-cocks, but leaving these in place. The cocks were closed before the pipes were unscrewed. The boxes were removed, and the holes well-rammed with grout, covering the stop-cocks and inner lengths of drain pipe. Some of the cocks had rusted so that they could not be closed, and at some points no cocks had been used. Under these circumstances, the horizontal pipes were filled with oakum, rammed tight, and then closed with conical plugs driven in. It is suggested that they might have been closed more quickly by iron nipples screwed in place, with threads well greased. The bleeders were shut off gradually, three or four each day, so as to throw the pressure gradually on the new 6-in. lining.

Fig. 3, is a view of the new lining, with the "bleeder" pipes, boxes and hose in place. In the middle of the shaft is the pipe for the drainage pump at the bottom. To the right of this are the brackets for the attachment of the permanent service ladder. Fig. 4, is a view at the upper end of the shaft, after completion of the work, with all holes closed and sealed. The dark patches do not represent leakage, but are damp spots due to condensation on the interior surface, resulting from the steam pipe which served the pump. This view shows the beams of the gate operating platform, and the operating gear, together with the ladder. It will be noticed that the surface shows a very close and smooth finish.

The work has proved quite successful, the lining being hard and impervious and entirely watertight.

SEWAGE TREATMENT by means of a grit chamber, double screening, percolating filters and rapid sand filters is practiced at Rothwell, England. We append a brief description of the works, taken from the London "Contract Journal," condensed from a paper before the recent Health Congress at Leeds, England. The paper was prepared by Mr. E. J. Silcock, M. Inst. C. E., and the condensation just named is as follows:

On arrival at the sewage works the sewage is passed through a small grit and screening tank, and is then pumped to a special revolving screen with a fine mesh. After passing the screen the liquid with all the suspended solids other than those which have been removed by the grit tank and screens is taken direct to deep percolating bacteria beds constructed with very large medium and designed to allow a free passage to the solid matter. The effluent from these bacteria beds is subsequently passed through ordinary sand filters, which are worked as mechanical strainers only, exactly like an ordinary waterworks filter, and by them the suspended matter is arrested. The filtered effluent is discharged into a small watercourse connecting directly with the River Aire. The sand filters are constructed of such an area as to permit of some being dried whilst others are at work. It is found that the material arrested by the sand filters quickly dries to a consistency which can be skimmed off the surface of the sand with spades, and when removed it soon falls to powder. Analyses of the deposit on the sand filters show that it has an earthy odor and a slightly alkaline reaction; it contains about 58% of moisture, and the dried sludge loses about 25% on ignition. A microscopic examination reveals sandy and dark brown particles, some vegetable debris, unicelluiar algae, a few diatoms and nemertoid worms. The works have been in operation since September, 1906, and the resulting effluent has been satisfactory to the West Riding Rivers Board. The author submits that under certain conditions it may be desirable to adopt this system of purification, which has the following advantages: (1) The sewage is treated fresh, and consequently there is no danger of smells arising from putrefaction. (2) The solid matter, by being passed through the oxidizing beds, is rendered innocuous, and is subsequently easily dealt with.

In commenting on Mr. Silcock's paper Dr. Gilbert T. Fowler, of Manchester, said he always thought the method embodied in the so-called "Leeds Filter" to be one of the best, for the reason that a minimum of time was taken in rendering the sewage inoffensive, and further that the conditions favored the growth of higher organisms—worms, larvae, etc.—which are coming to be regarded as among the chief agents in breaking down the organic matter of sewage.

Development of a Swiss Single-Phase Railway.—The Seebach-Wettingen Line.

By F. P. MANN.*

Electric operation of many of the government-operated railroads of Switzerland has been often suggested. Several waterfalls are owned or controlled by the government and from these the necessary power might be developed. In order to test the possibility of operating heavy electric locomotives for general and regular service and to secure a working line on which types of apparatus might be developed under practical working conditions, the Oerlikon Machine Works, of Oerlikon, near Zurich, proposed, in February, 1902, to take up at its own expense the equipment of the Seebach-Wettingen line, of the Swiss Federal Railways, a standard-gage line near Zurich some 12 miles long. The proposal was accepted in principle in May, 1902, and the plans for the first section, Seebach-Affoltern, were turned over to the Federal Railways in November, 1902. These plans were modified and approved in March, 1904, and meanwhile the Oerlikon Works had built and equipped a 700-meter line from their works to the railway, at Seebach. Late in 1904, the equipment of the Seebach-Affoltern section was completed so that trains could be hauled.

The locomotive used up to this time was a rotary-converter type, but in November, 1905, one with single-phase driving motors was put

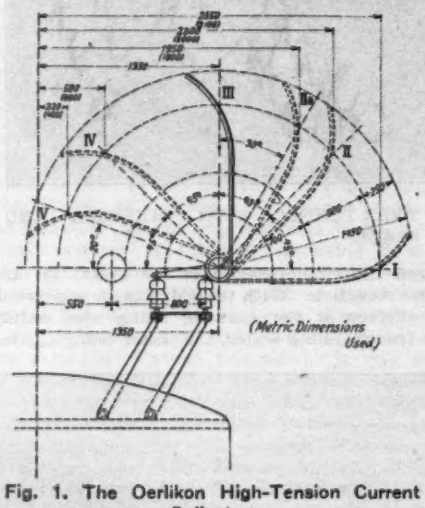


Fig. 1. The Oerlikon High-Tension Current Collector.

on and the older one was rebuilt to use them. In January, 1906, permission was given to extend the line to Regensdorp. At this time the Siemens-Schuckert Co. assumed an interest in the project, equipped the line from Regensdorp to Wettingen and contributed one heavy locomotive. The equipment of the whole 12 miles between Seebach and Wettingen, under the joint agreement, was complete after October, 1907.

Trains were run regularly after that time, and on only three occasions in the following year was it necessary to have recourse to steam locomotives. Two of these were due to line troubles and one to an accident in a substation. Some trouble was found in telegraph and telephone-line disturbances, but these were finally overcome. It is now announced that the period has ended for which these companies were permitted to use the line for electric traction and the use of steam locomotives has been resumed. This action was made necessary by the attitude of the officials of the Federal Railways and was contrary to the expectations of the concerns which built and installed the electrical equipment. The operation of the electric trains ended on July 3, 1909, and the electrical material is now being removed. The following paragraphs, translated from the annual report of the Oerlikon company, presented at its annual meeting on Sept. 29, 1909, show the company's attitude toward the project.

The electrical operation of the Seebach-Wettingen section which was begun Dec. 1, 1907, and was to be operated by us in connection with the Federal railways until Dec. 1, 1908, was continued by agreement with the Federal Roads until July 3, 1909, at which date it was discontinued. From the start the electric locomotives, working on the time table of the line, ran 129,710 train-kilometers (80,600 train miles) with 6,704,860 gross (long) ton-kilometers (10,380,000 ton miles).

As early as 1901 we found that the systems already designed were scarcely applicable to railway work, especially for the operating conditions and gradients in Switzerland. We then studied the 15,000-volt, 15-cycle system and brought out locomotives for it. At the same time we made arrangements with the Federal railways for use of the Seebach-Wettingen section for trials in actual commercial service. According to our agreement the plant was to be under the general control of the Federal railways but we were to furnish the locomotives, current and service personnel at our expense. We were to run the trains on the regular schedule for 12 months, being responsible for all damage to persons and goods. The Federal railways were to allow us 60 centimes per train-kilometer. After test they could either make an agreement to take over the electrical apparatus or they could have it removed. The plant finally comprised, the overhead construction of the main line and the wiring of station points, three locomotives, a locomotive shed at the Seebach station, an electric generating station and a rotary-converter station with storage battery, the latter two being on the Oerlikon company's property. The western end of the Seebach-Wettingen overhead line and one locomotive were installed by the firm of Siemens-Schuckert with which, it is well known, we are doing business in common for Switzerland. The development of the electric system was carried on by different stages and finally reached the above proportions. We were obliged to take measures to overcome telephone disturbances in the suburban lines passing nearby. These were successful. We also had to operate our system not only as to its financing and unification of apparatus, but also for its best manipulation by employees and for convenient service.

When we had attained these ends, we believed that the time had come to settle the final disposition of the system, and we negotiated with the Director General of the Federal Railways for taking it over. The negotiations did not end satisfactorily for us. We then proposed to lessen the cost per train-kilometer of operation, since we expected that the Federal Railways would finally take over the line.

Regarding the results of these tests: Our standards developed have been shown to be excellent and are being adopted in various new projects on the Continent. To give an example in Switzerland, we have the use of our system on the Loetschberg line which is now being built by the Bernese Alps Co. The system is approved by numerous engineers. It is hoped that with the system developed and tried with success on the Seebach-Wettingen line and to be used on the Loetschberg railway, and on others building or projected, we will reach the point when many Swiss main lines will use this electric system.

It seems probable that the Seebach-Wettingen line will go into the history of electrical projects along with the Marienfeld-Zossen experimental high-speed line of 1901-3, and with the first high-tension power-transmission line between Lauffen and Frankfort of 1891. There is one notable difference, however, as these two earlier projects were intended from the outset as experimental, while the Seebach-Wettingen installation apparently was to be permanent if successful. It is to be regretted, therefore, that the Director of the Swiss Federal Railways has made no statement on the suppression of electric traction here and that the Oerlikon company did not continue to operate the system until the cost of operation had reached a minimum. It should be borne in mind, however, that the Seebach-Wettingen line was probably selected on account of its accessibility to the Oerlikon works rather than on account of inherent adaptability to cheap electric traction. The apparatus developed is briefly discussed in what follows. The writer acknowledges his indebtedness in many ways to the papers of Mr. Hugo Studer, of Zurich, in Vol. LI. of the "Schweizerische Bauzeitung," Nos. 15-20, and to the officers of the Oerlikon Works.

Overhead Construction.

OERLIKON WORKS.—To understand the reasons for the peculiar overhead construction designed by the Oerlikon engineers, it is necessary to look at the collecting antennae, shown in Fig. 1. Each consists essentially of a bent Maunesman tube carrying a removable facing where the tube would bear on the trolley wire. Two of these arms are mounted on a frame, supported

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by insulators, in such a way that they may revolve 180° transversely to the car axis, this arc being entirely above the horizontal. The collector frame is mounted also on two hinged arms so that the whole apparatus can be shifted from or towards the centerline of the track by rotating the hinged arms. In this motion the hinged arms always form sides of a parallelogram. The collector mechanism can be operated by hand or by compressed air.

The trolley wire was of copper, 8 mm. (32 ins.) in diameter, variously suspended and supported under different conditions. At the Seebach station it is suspended from a simple catenary of steel wire of 6 mm. (0.24-in.) diameter. On parallel extensions about this station, cross catenaries were stretched between wooden poles and the trolley conductor was suspended and guyed by vertical and horizontal wires fastened to an insulated ring which is attached to the top of the trolley wire as shown in Figs. 6 and 7. On such stretches the trolley is 5 meters (16.4 ft.) above the trolley. The wire was run in many places on top of poles (steel rails) at the side of the track as shown in Fig. 2. Here the trolley wire was but 4.5 meters (14.7 ft.) above the track. Fig. 2 also shows the way of making certain sections of the working trolley dead or alive as desired. A second trolley wire is deadended on a pole carrying a horn switch, but crosses out under the first trolley and takes its place on the insulator nearer the track, while the regular wire passes to the second insulator or rises on high poles over much frequented crossings. In such cases the horn switch may be operated by the gateman through the rope shown.

Fig. 2. Construction By the Oerlikon Works at a Section End.

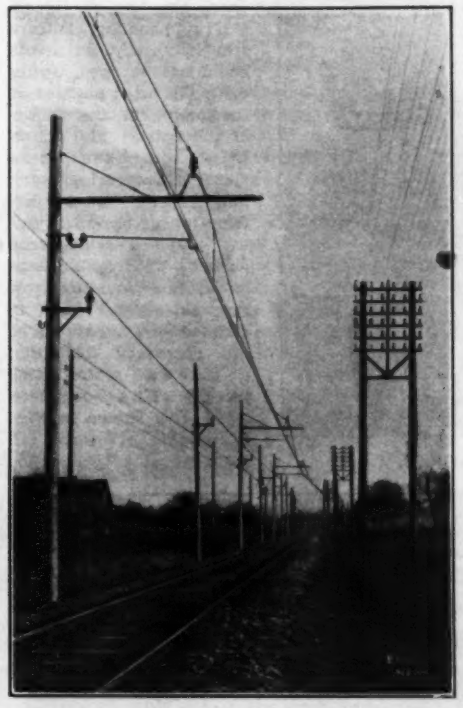

Fig. 3. A Stretch of Line Having the Construction of Both Siemens-Schuckert and Oerlikon Companies.

FIGS. 2 AND 3. TYPICAL OVERHEAD CONSTRUCTION. SEEBACH-WETTINGEN LINE.

On much of the line the trolley wire was arranged for side contact so that the trolley quill was vertical. The trolley wire is here carried at a height of 5.4 meters (17.7 ft.) by an insulator on a bracket fastened to the side of the pole, as shown in Fig. 3. This arrangement was considered desirable for stretches on which high speeds were reached as the vertical sag of the wires did not interfere with proper contact between the quill and wire, and the evil effect of the rigidity of supports was minimized. A single type of insulator was used on all work. This is shown in Fig. 4. It is of porcelain fixed on the end of a metal pin with tow and bearing a cast-iron cap which supports the trolley wire. The supporting lug on the iron cap may be on the top or side as found best in each case. Where the pole has to be far out from the trolley wire two insulators are used, one carrying a horizontal pipe arm and the other a guy wire with a turnbuckle, as shown in Figs. 4 and 5.

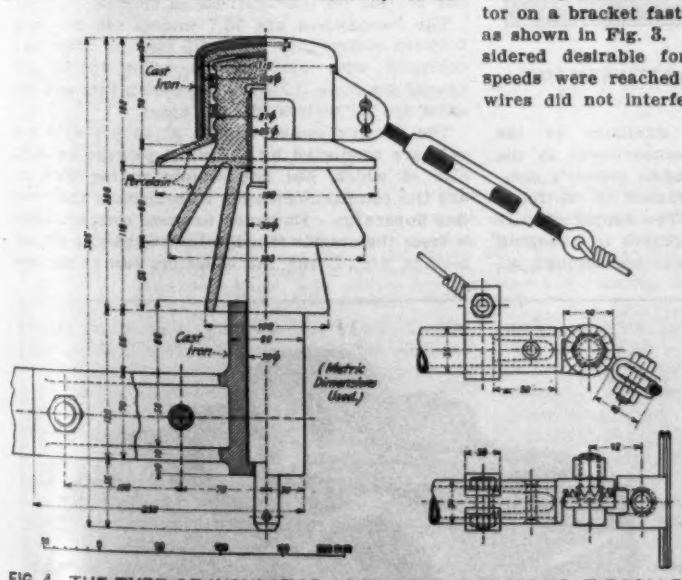

FIG. 4. THE TYPE OF INSULATOR USED ON THE 15,000-VOLT TROLLEY OF THE SEEBACH-WETTINGEN LINE.

What is known as a "disconnecting line" runs the whole length of the Oerlikon construction, and is shown in Figs. 2, 3 and 5. This is a steel wire, carried on small insulators and connected by fuses to all the pins of insulators on the main line. At the supply station it is grounded through an electromagnetic relay. When any current passes through this relay it opens the main-line switches. The passage of current through the fuse breaks the fuse cartridge, and as the ruptured ends are easily distinguished a simple inspection of the line localizes the trouble.

SIEMENS OVERHEAD CONSTRUCTION.—About half the system, or from Regensdorp to Wettingen, was equipped by the Siemens-Schuckert company. The two systems of overhead construction ran parallel for about half a mile after leaving Regensdorp, so that the change over from one collector to the other could be made without interfering with the speed of the train. This is shown in Fig. 3.

The Siemens-Schuckert type of collector is shown in Figs. 6 and 7. Two U-tubes come to a common joint which carries a light aluminum trailing frame. A spring mechanism at the ends of the U-tubes forces the common joint and trailing frame upward. The collector works in either direction, and when the locomotive is running the trailing frame is inclined toward the rear by about 30° from the vertical. It is claimed that its ease of rotation and lightness make contact certain even at the highest speeds. Raising and lowering is by compressed air.

The trolley wire is supported by a double-catenary construction which needs little explanation. The main catenary was a cable of 35 sq. mm. area (0.005 sq. in.); the auxiliary catenary was a wire of 28.3 sq. mm. area (0.0044 sq. in.). The trolley wire was of copper 100 sq. mm. (0.0155 sq. in.) in section, of figure 8 shape, and was suspended from the auxiliary catenary by grips about 3 meters (9.85 ft.) apart. The hangers, of 19.7 sq. mm. cross section (0.0031 sq. in.), which supported the auxiliary catenary were about 6 meters (19.7 ft.) apart. The insulated anchorages of the main catenary were some 50 meters (164 ft.) apart. The cable was fastened to the iron cap of the insulator already described. On open stretches of track, wooden poles supported steel brackets; at stations one, or more, steel poles supported a long bracket arm bearing the insulators. At each station there were section breaks, normally closed and locked, with the key deposited near by.

The trolley wire was zig-zagged across the center line of the track to distribute the wear on the collector bar. At the end of a section the new section of trolley wire with independent catenary supports was continued parallel for two or three poles. Then the old section of trolley passed out toward the side and all three wires were dead ended at a pole. The trolley wire of a new section started at an automatic tension adjuster. This consisted essentially of a weighted cable passing over sheaves on a pole and attached to the trolley through an insulator.

TRACK BONDING.—The rails were bonded with round copper conductor of 50 sq. mm. (0.0078 sq. in.) cross section and in some places with copper strip 20 × 1.25 mm. (7.89 × 0.493 ins.). The rails are grounded by large iron plates once in about each two kilometers (1.24 miles).

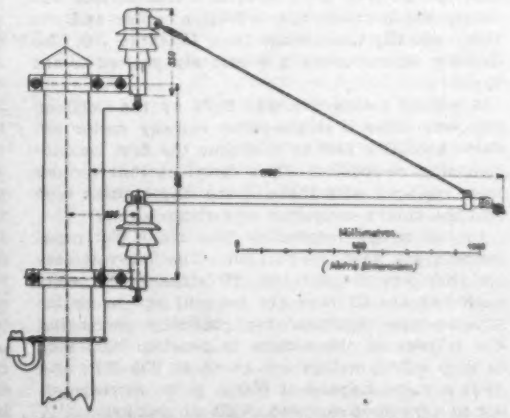

Fig. 5. Extension Bracket For Side Trolley and "Disconnecting Line" Connections.

Locomotives.

OERLIKON WORKS.—The first engine was built before a satisfactory single-phase railway motor had been developed and accordingly was equipped with direct-current motors supplied

from a rotary converter. This was a 700-volt induction motor coupled to a 600-volt, 400-KW. generator. An exciter for the driving motors was mounted on the converter shaft and served also as a starting motor running then as a series motor on single-phase supply at 150 volts. For normal operation of the converter a transformer was interposed between the induction motor and the line, reducing the voltage from 15,000 to 700. The driving motors were a separately excited shunt type.

FIG. 6. DESIGN BY THE OERLIKON WORKS.

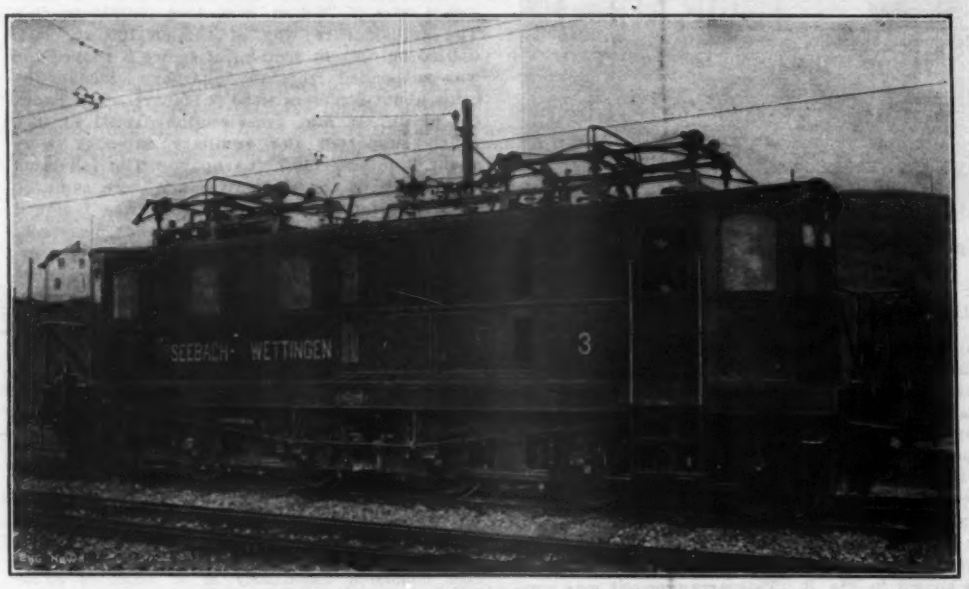

FIG. 7. DESIGN BY THE SIEMENS-SCHUCKERT COMPANY.

FIGS. 6 AND 7. SWISS AND GERMAN LOCOMOTIVES OF THE SEEBACH-WETTINGEN LINE. FEDERAL RAILWAYS OF SWITZERLAND.

A second locomotive was built by the Oerlikon company after a single-phase railway motor became available and at this time the first locomotive was remodeled. The direct-current motors were replaced with those of the single-phase type and the rotary converter was removed.

In the newer locomotive two 250-KW. transformers are used, in parallel. The 700-volt secondaries are divided into 20 steps of 35 volts each and the 21 taps are brought out to an induction-type regulator for gradually increasing the voltage on the motors in passing from step to step. The motors are rated at 250 HP. and have a normal speed of 650 r. p. m. corresponding to a locomotive speed of 40 mi. per hr.

The mechanical parts of these two engines are similar and a few words on one will apply to both. Each locomotive has two two-axle bogie trucks with a single motor suspended, on each truck, between the axles. The motor is above the wheels and under it is the intermediate shaft to which it is geared (reduction of 1 to 3.08). On the ends of the countershaft are balanced cranks working in a sliding bearing at the center of the driving bar. All this is shown in Fig. 9. The drivers are one meter (3.28 ft.) in diameter. The tractive effort is transmitted by the cab frame and buffing shocks are received by it. The cab is set on the trucks with vertical springs and lateral guides interposed. Stresses are transferred from the trucks by oblique rods, of which there are two per truck. This peculiar feature was necessary, as pivots could not be used, owing to the elevated position of the motor in the center of the truck. The points about which the trucks rotate in service vary and depend on the inclination of the rods and the play of attachment points. The truck frame is spring mounted on the axles and this is claimed to allow all the necessary flexibility between motor and track. The complete locomotive shown in Fig. 6 weighs 47 tons (of 2,000 lbs.).

The electrical apparatus, auxiliary to the motors, is assembled in a compartment in the center of the cab with the engine runner's compartment at the ends. The system of control is shown generally by Fig. 9. The supply of current to the motor is uninterrupted in changing from one controller point to another through interposing the preventive transformer H. T. (Fig. 9). This coil has its middle point always connected to the motors and by advancing alternate ends for connection to the main transformer leads, an unbroken motor current at gradually increasing voltage is secured. Hand operated reversing switches are mounted on the partitions between the apparatus and driver's compartments. At the driver's hand are, besides the controller, (1) a hand brake, (2) air valve for Siemens collector, (3) air valve for Oerlikon collector, (4) air valve for sand box, (5) Westinghouse brake valve.

The motors alone have several points of novelty for Americans. Their electrical scheme is shown in Fig. 9. They are of an open type designed to run at from 650 to 1,000 r. p. m. The field is of laminated construction, with eight main and eight commutating poles. These small poles produce a flux approximately at 90° to the normal field, and current in these coils is regulated in phase and value by a shunt resistance, so that the commutating poles induce, in those few armature conductors which happen to be momentarily short circuited by the brushes, an e. m. f. opposite and equal to that induced in those same short circuited conductors by revolving in the main field and by the alternations of that field. This prevents sparking and removes the necessity of resistance ("preventive leads") between the commutator bars and the armature windings. This design, it is claimed, is entirely successful under the most unfavorable loadings.

The supply of compressed air comes from an automatic motor-driven compressor, with storage in the tanks, seen in Fig. 6, extending the length of the frame.

SIEMENS-SCHUCKERT TYPE.—The third locomotive, placed in operation on the Wettingen end of the line, differs materially from the Oerlikon design as is at once evident from Fig. 7. The trucks are of the general type developed from the high-speed tests on the Marienfeld-Zossen line in Germany. These trucks were designed to carry three motors, though they were here equipped with only two. Two motors would be suspended between the outer and center axles of each truck and one between the center and inner axles. The motors are geared to the axles of driving wheels and both motors and drivers have their centers in one plane.

The trucks engage the frame of the engine body by pivots, but cushioned lateral play of these is permitted. This allows an easier entrance onto curves and has been found generally satisfactory in reducing the shocks which arise from rolling at high speeds. The weight of the body is placed on the trucks through shoes, four to each truck. This arrangement entirely relieves the pivots of the weight of the body and auxiliary apparatus. The coupler and buffers are mounted on the ends of the trucks so that stresses and shocks are carried by the frame only between the truck pivots. The total load on the truck frame is transferred to the axles by spring suspensions. It will be seen from Fig. 7 that the load on the outer axles of each truck are partially equalized by a pivoted bar bearing on the usual coiled springs.

The locomotives are 13.7 meters (45 ft.) long between buffers, and weigh 75 tons (of 2,000 lbs.) equipped with four motors. The trucks are spaced 6 meters (19.7 ft.) between pivots and the axles are 2.1 meters (6.9 ft.) apart.

The driver's compartments, at each end of the cab, are connected by a central passage on each side of which, but not communicating with it, are the compartments for transformers and control apparatus. Entrance to these compartments is from the outside through the bolted side plates, seen in Fig. 7, and the collectors can be thrown

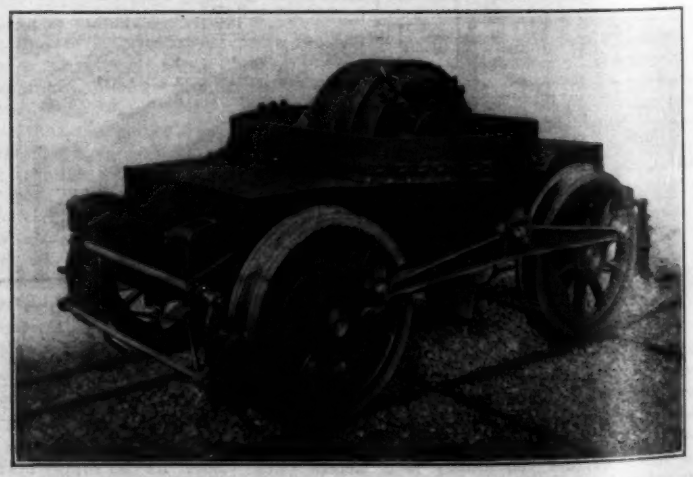

FIG. 8. MOTOR TRUCK OF THE OERLIKON LOCOMOTIVE.

up only when the doors are on. Taking the doors off grounds the high-tension circuits. There are two transformers, one in each side compartment. On the doors to these compartments are gratings with wings deflected outward toward the ends of the cab, so that when the locomotive is in motion in either direction a supply of fresh air in the transformer compartment is insured. The transformers are an air-cooled type of 500-KW. capacity and reduce the line voltage (15,000) to 288 + 330 + 378, the secondary being split into three sections for motor control.

High-tension, oil-break, overload-release, automatic switches are placed in the circuit leading to the transformer primaries. They can be thrown at will from the driver's compartment. In the apparatus compartments are also the general fuses and the magnetic switches, controlling the motor speed, arranged in banks for each motor.

For the control of the motors, those on each truck are connected permanently in series. The three sections of the transformer secondaries are

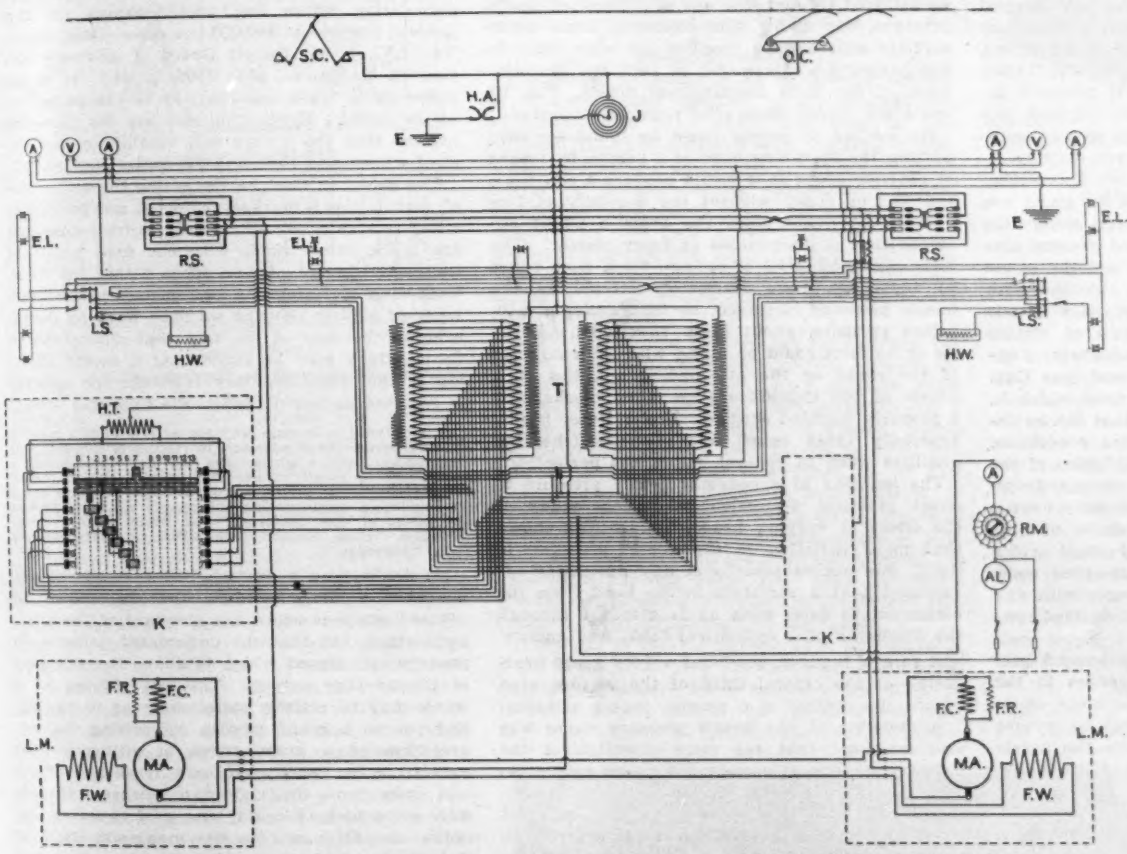

FIG. 9. DIAGRAM OF ELECTRICAL CONNECTIONS OF OERLIKON DESIGN OF SINGLE-PHASE ELECTRIC LOCOMOTIVE.

(A, Ammeter; V, Voltmeter; O.C., Oerlikon Collector; S.C., Siemens Collector; E, Ground Connection; H.A., Horn Lightning Arrester; J, Impedence Coil; E.L., Lamps; R.S., Reversing Switch; L.S., Lighting Switchboard; H.W., Heaters; H.T., Auxiliary Controller Transformer; T, Main Transformers; K, Controller; R.M., Compressor Motor; A.L., Air-pressure Regulator; L.M., Driving Motors; M.A., Rotor; F.C., Auxiliary Field; F.W., Main Field; F.R., Auxiliary-Field Rheostat.)

slipped, by three stages, into the motor circuits. The motors of each truck are connected with one transformer only. The switches themselves are operated by electromagnets which are in turn actuated by a current of low voltage from the driving controller.

The motors found on this engine are an eight-pole, iron-clad, commutator type with forced ventilation from a fan carried in the cab. The frame is a steel body 810 mm. (32 ins.) in diameter, holding the laminated iron fields. This stator has auxiliary commutation fields whose function is largely to compensate for the e. m. f. generated in the coils short circuited during commutation and thus to prevent sparking. To cut down the short-circuit starting current resistance is placed between the rotor coils and their respective commutator bars. This resistance is in the form of a conductor laid on top of the coils so as to partly compensate for the added heat loss by an increase in the starting torque. The field windings are laid in two slots for each pole and the commutating field is superimposed in slots as left free after the other work. This arrangement allows two exciting windings which are used alternately as regular and auxiliary fields, according to the direction of running of the locomotive.

Aerial Distribution of Sewage Over Percolating Filters.*

By WM. GAVIN TAYLOR,† M. Am. Soc. C. E.

The Problem.

The problem of distributing sewage over the surface of percolating filters has developed, as our knowledge of the action of such filters has increased, into one of far greater complexity than was at first supposed by engineers.

In attempting to apply a foul liquid, such as sewage, with perfect uniformity over the surface of a large area, one meets many adverse conditions, which must be carefully studied and either overcome through proper design or in some way avoided. It was at first thought, and many may be found to-day who still believe, that the highest possible or practicable efficiency in the surface distribution of sewage is not an absolutely essential element in the operation of a percolating filter. To partially bolster up such a thought, refuge has been taken in the hope that the inequalities in surface distribution would be quickly equalized in the percolation of the applied sewage through the upper few inches of the filter material and that, thereinbelow, a considerable degree of uniformity of distribution would exist through a dividing and a redividing action taking place in the film of descending sewage.

But, unfortunately, this ideal condition has not proved to be a fact. If the efficiency of this lateral or subsurface distribution really existed, it would greatly simplify the problem in hand and make unnecessary many refinements in the design and construction of distributing devices which aim at increasing the perfection of surface distribution. But, unfortunately, the subsurface distribution of the sewage film is not marked, or always a positive factor, while it is, on the other hand, frequently negative in character.

The writer has demonstrated in a series of proper tests, briefly described in the Engineering Record for June 5, 1909, p. 710, the extent of the diffusion produced by a film of liquid, of a given character, in passing downward through material suitable for percolating filter construction. The material used in the tests was carefully graded as to size, and ranged from a ⅛-in. to a 2-in. broken stone. The tests clearly show that, with the application of liquid at a point on the surface, there results a definite diffusion of the liquid film throughout a parobolic cone of the filter material, the apex of the diffusion cone being at the surface. In general, the major portion of the lateral distribution is effected in the first foot of material, and the film, as it descends, tends to travel in a path ever approaching the vertical. While this diffusion from a single center of application was definite and calculable, the principle did not hold good when the number of application centers was increased from one to several or many. Under the latter conditions of application there existed, within the filter material, as many opposing diffusion cones as there were points, or centers, of application, with the result that the films of liquid from the interlacing diffusion cones united to form a film of greater thickness, and, as the depth increased, into tiny and then into larger streams, which thereafter tended to travel along a more nearly vertical path than before. This streaming effect became more pronounced as the rapidity or inequality of surface application increased.

Study along these lines has shown conclusively that to obtain the maximum permissible rate or the highest possible efficiency under a fixed rate from a given filter operating under a particular set of conditions, it is essential to obtain the highest possible degree of uniformity in the surface distribution. It should be aimed to apply to every infinitesimal area of exposed surface an equal amount of sewage, as it is only through such perfection that we can hope to cause each unit area of bacterial surface within a filter to perform a like amount and quality of work.

We have seen that no dependence can be placed upon the filter media to effect a diffusion of the influent, neither can we rely to any great extent upon the diffusing effect of the wind during the flight of the influent through the air. Wind action is surely helpful in splitting up the larger particles into smaller ones and in causing a better diffusion from an inefficient device, yet in general the wind action should be considered as a disadvantageous rather than a helpful factor, inasmuch as the least excess causes a fouling of the adjacent filter edges and paths. The aim, for maximum service, is then to attain uniformity in surface distribution or, in other and more forceful words, the perfection of distribution should be *aerial*. Such is the ideal that presents itself, and the nearer we approach it, in the practical operation of percolating filters, the greater becomes the permissible rate of operation for a given degree of oxidation.

*A resumé of studies made at Waterbury, Conn., prior to 1909.

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Distributor Types.

In the construction of many early filters great reliance was placed upon the distributing action of the filter material and the winds. The assumption that these influences would be effective in the production of sufficient efficiency, together with the absence of present-day knowledge of percolating filters, led to the adoption of very simple and inefficient distributing devices, but the use of such crude apparatus was justified, no doubt, by reason of the experimental state of coarse-grain sewage filters then being passed through.

At Chesterfield, England, the influent pipes were held by supports just above the filter surface and tubes tapped therein at intervals, permitting the ejection of vertical columns of sewage, which were more or less diffused over the filter surface by striking an inclined splay board secured a few inches above the tubes. During windy periods the efficiency of the diffusion was, naturally, somewhat greater than during normal weather. Another type of distributors having still less efficiency was installed at several plants. Under this method the filter surface was prepared into a series of low ridges and furrows. The influent pipes were laid along the valley lines and arranged, by tappings at frequent intervals, for the discharge of small inclined jets which rose from the upper portion of the feeder and played on the surface of an adjacent ridge.

Other types of crude and inefficient distributing devices were used, but the examples given are sufficient to show the early efforts along this line. Gradually the desirability of greater uniformity in application was realized by some workers, and better results were obtained both through improved construction of fixed nozzle heads and through the development of rotable and traveling machines. At Birmingham, England, a type of nozzle has been used (see Eng. News, Vol. LX., p. 200, for illustration) which is, perhaps, as efficient as any nozzle that can be designed for use under the prescribed conditions, namely: a constant head and the diffusion of the applied sewage into a myriad of minute drops, which it is aimed to distribute uniformly over a circular area. The structural details of this nozzle, together with the relatively small orifice area and the closeness of the impinging cone, absolutely debar the use of the nozzle with any but the most carefully prepared and clarified sewage.

Yet, even with a sewage as well treated preliminarily as at Birmingham, stoppages in the nozzles are very frequent and the labor of at least two men is constantly required to remove the obstructions accumulating within the nozzle dome (Eng. Record, Vol. LIX., p. 160; H. W. Clark, Eng. Record, Vol. LIX., p. 138) on four one-acre units at the Saltley works.

If, then, the Birmingham nozzle, which represents the practicable limit of efficiency of a fixed nozzle head, actuated under a constant pressure and attempting a uniform distribution over a fixed area, effectively uses only from 50% to 60% of the filter volume (Clark, Eng. Record, Vol. LIX., p. 138), the fact emphasizes the essential need of discovering some new method or principle of operation whereby a far greater portion of the filter volume is efficiently used.

In England revolving and traveling distributors of many sorts are in successful operation, and some of them effect an almost ideal distribution. By reason of the tempering influences of the Gulf Stream, the climatic conditions there are such as to make the operation of these mechanical devices entirely practicable, upon uncovered filters, throughout almost every day of the year. In fact, only exceptional storms or excessively low temperatures are sufficient to render the best devices inoperative. Two such stoppages occurring in south of England towns have been cited (Eng. News, Vol. LVII., p. 215) in which the accumulation of ice stopped the rotation of the distributor and securely bound the parts in an immense body of ice.

In the Waterbury (Conn.) studies for the development of its sewage purification work it was early decided that both the traveling and the rotating distributors were inapplicable, owing to the long periods of low temperature experienced in this portion of New England, the frequent and severe snow and ice storms of winter, the exposed position of the proposed filter beds, the excessive cost of installation and maintenance of such types, and other reasons. Nothing was done relative to traveling distributors save the making of a general study and the designing of a rotable, three-armed trough distributor for experimental purposes, having staggered V notches so arranged as to produce very perfect distribution. The device was supported upon a central post, revolved upon a thrust ball-bearing, rotated by the expenditure of energy in the influent sewage through a principle similar to that in the steam turbine; the whole was simple, easily cleaned, and uncloggable. A study of fixed nozzles followed, along original lines, and many types of nozzles were designed, tested, and most of them discarded as a whole, although the favorable points were aggregated and incorporated in new types as the work progressed.

It was shown that perfect uniformity could not be attained through the use of a constant nozzle pressure, for under this condition some intermediate zone always received far more than its due proportion of sewage; in fact, the performance of the little Birmingham nozzle, Fig. 10, could not, under these conditions, be exceeded.

No method or means could be found for supporting the spreading cone of a nozzle, by means of exterior arms, that would produce a self-healing film or spray without the necessity of frequently removing from the arms a slight accumulation of filamentous or hairy matter. The self-healing qualities of sewage films, from cones so supported, were markedly bettered as the nozzle pressure increased, so that under a 5-lb. orifice pressure, about 12-ft. effective head, little or no fault could be found with the character of the spray or the self-healing qualities of a nozzle of the Columbus type when discharging a properly clarified sewage. Under lesser heads, especially those below 5 ft., the self-healing qualities were, in general, much less perfect.

The inability of a constant nozzle pressure to effect practical perfection led to the study of the effect of varying heads, and it was shown that mere variation in the nozzle pressure, in itself, was not necessarily of any particular advantage; that a variation in the head from the maximum to zero, such as is attained through the discharge of a cylindrical tank, and equivalent to a $\sqrt{h}$ curve, produced a very great overdosing of the central third of the surface area within the control of a nozzle; that a straight-line variation in the nozzle pressure curve was also fruitless; that the mere cessation of the nozzle discharge at some point above zero pressure was often helpful, but alone it was insufficient to produce the desired effect; and finally it was found that for a variation in the pressure to be of marked service in the betterment of the efficiency or perfection of distribution, the said variation must be under perfect and positive control, throughout the dosing cycle, as will hereinafter be exemplified.

During the studies the following fact of notable importance was discovered: that all sewage nozzles previously made in Waterbury and elsewhere, so far as is known, had for their primal duty the attempt to cover a definite *surface area* bounded by a circumference dependent upon the covering radius of the nozzle. This thought does not show its full meaning and value until the exact opposite is stated: that possibly greater perfection might be attained in the uniformity of distribution if the duty of a fixed nozzle was changed from the covering of a definite *surface area* to the concentration of the discharged liquid upon a definite *periphery*. It was at once recognized that a sewage nozzle having such a structural formation as to effect a concentration of the influent into an extremely thin film, preferably of a one-drop thickness, would, under a constant nozzle pressure, such as was theretofore commonly used, produce a highly improper distribution; in fact all of the sewage would be discharged upon one very narrow zone, theoretically of infinitesimal width.

For theoretical perfection there remained only the need of effecting a reduction in the actual pressure on the nozzle orifice so that the wetted periphery would be reduced from the maximum to zero with mathematical precision. In theory this doctrine is rational and easily thinkable; in practice numerous difficulties are encountered, but in the main they can be subjected.

Economy in the construction of percolating filters demands the use of large units where possible and these are normally rectangular, although other geometrical forms sometimes have peculiar merit. Traveling distributors, such as are in use at Hanley, England, have the marked advantage of bringing into active use all portions of the surface area, whereas circular spray nozzles, rectangularly placed, can cover only 78% of the total surface area, the remaining 22% being wasted so far as actual service in purification is concerned. Such a loss in usefulness has a tremendous money value, for it represents 22% of the total cost of a unit, or nearly $9,000 per acre of beds, if we assume the cost of high-grade percolating filters and appurtenances for this general purpose at $40,000 per acre. (Eng. News, Vol. LX., p. 58; Report Board of Advisory Engineers, Baltimore, Md., 1906, p. 44.) It is not sufficient to lower our ideal as to the perfection of the surface distribution and say—So place the nozzles that the sprays will overlap to any desired extent and thus wet the entire surface.

The defect in this premise is that the uniformity of distribution is markedly affected, and particular areas receive many times their normal dose and are much overworked, with the final result of the establishment of sore spots within the filter. That such operation is a real menace to the character of a filter effluent we need have no doubt, even in the face of the fact that champions to the contrary may be found. At a recent meeting of the Royal Sanitary Institute one speaker is reported as having taken the following stand:

> It is difficult to explain why the defects of this method of distribution [fixed nozzles], in respect of inequality of distribution over a given area, do not bring about a corresponding result in the bed effluent, which theory would lead us to believe must inevitably occur. There are obviously compensating advantages which neutralize the effect of this deficiency, and which remain undetermined. (Eng. Record, Vol. LVIII., p. 261, abstract from "Surveyor.")

No doubt need be entertained that excessively overdosed volumes within a filter do produce an effluent which is below the standard of the average output, and that the underdosed volumes do produce an effluent which is above the standard of the average output. The bed effluent as a whole may be entirely satisfactory as to quality, and yet be a grand medley comprising the aggregation of a great range of effluents—poor ones from the much overdosed areas and excellent ones from the underdosed areas. If this were not a fact we could, with perfect safety, increase the filter rate to the maximum limit of the overdosed area, provided, however, that our distribution be uniform.

Certain filters have been in use, experimentally and otherwise, under a normal rate of 2,000,000 gals. per acre per day, in which small portions have been overdosed as much as six times the mean, and yet the general effluent was of fair quality. It is reasonable to believe, and it is a fact, that cessation in the mixing of high and low-standard effluents within the bed, by greater perfection in aerial distribution, will permit an increase in the normal rate of the filter, and that this possible increase in filter rate is some function of the efficiency of distribution. This thought has not as yet been widely appreciated, but its fulfilment offers great possibilities.

The staggering of the nozzles in alternate rows brings a hexagonal area under the normal control of each nozzle head and makes a closer lateral spacing possible, but even this method has not materially lessened the aggregate waste area when circular spray nozzles are used on rectangular beds, so far as present installations are concerned, for no attempt has been made, it is believed, to dose the semi-circular area present at one end of each nozzle feeder line under this arrangement. These unused semi-circular areas may, however, be well and completely covered, as has been done experimentally at Water-

bury, by inserting in the orifice of the nozzle, if it is of suitable design, a half-round rubber plug between the dome and the spindle.

Recording Results.

When sewage nozzles first came into use in the United States the work done by one was commonly designated in terms of the percentage of the total area that was wetted; thus it was said, for example, that 77% of the filter surface was wetted. This information gave no clue as to the uniformity of the distribution or at what rate

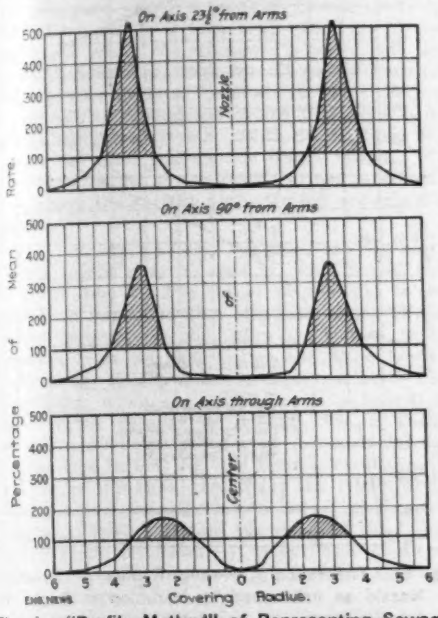

Fig. 1. "Profile Method" of Representing Sewage Distribution.

(Columbus Nozzle, 45°, 5-ft. constant head, still air.)

certain portions of the surface were overdosed. Later a somewhat more precise, yet inadequate, terminology was used in which it was stated that a definite percentage of sewage was applied to a definite portion of the filter, e. g., 77% of the sewage was applied to 42% of the filter surface. (Mass. State Bd. of H., 1906, p. 214.) In 1906, Phelps (Eng. News, Oct. 11, 1906) published a method of calculating a distribution coefficient for a sewage nozzle and Gage (Eng. News, Aug. 20, 1908) as a result of his work at Lawrence, published another. He also presented in the same paper a new method of recording, by means of contour lines, the work done by a nozzle under specific conditions. The figures resulting from this method of delineation (Eng. News, Vol. LX., p. 202) give precise information as to the equality of distribution and the extent of the overdosed areas, and are sufficiently clear to those frequently using such drawings.

To show in a more forceful manner the exact results effected by a nozzle doing good service under constant pressure, Fig. 1 was prepared from data contained in Gage's paper above cited. The drawing presents to the eye, at a glance, a clear conception of the great irregularity and the marked overdosing of particular parts of the surface area when dosed, by a nozzle of good design, under a constant pressure. And it is this thought which the writer wishes to emphasize in presenting this figure: the absolute necessity, if high efficiency in distribution is to be attained, of operating fixed sewage nozzles under a properly-controlled orifice pressure that shall vary, through the dosing cycle, from the maximum to the minimum according to a predetermined curve.

The shaded portions in the diagram (Fig. 1) represent the extent and the intensity of the overdosing and show that portions of the filter surface would receive, under these conditions, an application at more than five times the mean rate; that is, if the filter was operating at an average daily rate of 2,000,000 gals. per acre these maximum overdosed areas would be operating under a 10,000,000-gal. rate. We must bear in mind, however, that the particular test in question was made in still air, and that consequently it does not represent with exactness the distribution that might be obtained in practical operation, where the spray is at times lashed by the wind. Under these conditions the crest of the overdosing would be broadened, materially lowered, and the uniformity of distribution somewhat improved.

Another method was devised for recording the actual distribution effected by a sewage nozzle, which, perhaps, shows the results in the most forcible manner possible. The method consists of making a relief map or model from a contour drawing of the type used by Gage. In this manner a model was prepared, in wood and wax, based upon the same test which underlies Fig. 1. From the original model several casts were made, both in plaster of Paris and in aluminum. A half-tone reproduction of one of these models is shown in Fig. 2. A clear conception of the full meaning of such a model is obtained if we imagine that the sewage nozzle discharges a viscous fluid, which upon being deposited solidifies into a jelly and builds up the irregularly shaped mound shown in the illustration.

Test Apparatus.

The design of many types of sewage nozzles at Waterbury has resulted in the gradual development of a type which will later be described. That the merits of each progressive type might be definitely discovered it was necessary to provide a suitable testing apparatus, and one was constructed based upon the same general principle as that used in the Lawrence tests by Gage (Eng. News, Vol. LX., p. 199, and 39th An. Rep. Mass. State Board of Health, 1907, p. 190), although the apparatus differed in a number of important details.

A stand-pipe was erected, for maintaining the requisite pressure conditions, having suitable inlet and outlet connections. At a suitable nearby point the outlet pipe rose vertically to a height of about 2 ft. from the ground, which had been covered with very porous material and thoroughly underdrained. At the top of this riser provision was made for the reception of any type of nozzle. A collecting board, arranged for the support of a series of rain gages of 6-in. diameter, was yoked to the riser and adapted for orientation through about 110°, thus permitting a study of the radial distribution throughout this sector without adjustment of the nozzle.

Collection of the discharged fluid was made in 1-qt. Mason fruit jars, the bases of which fitted snugly into square holes, spaced 6 ins. c. to c., in the collection board. In the mouth of each jar was placed a special tin funnel having soldered to its top a thin vertical rim exactly 6 ins. in diameter. The particular object of this rim was to prevent a spattering of the striking drops and thus counteract an action which, if left free, would have resulted in a material under-registering. With a nozzle in action the distant funnels received a play of spray upon their exposed outer surfaces, and a portion of such spray would, if undiverted, find its way to the jars, causing an over-registering. This tendency was averted by soldering a band, having a diameter slightly larger than the lip of the jar,

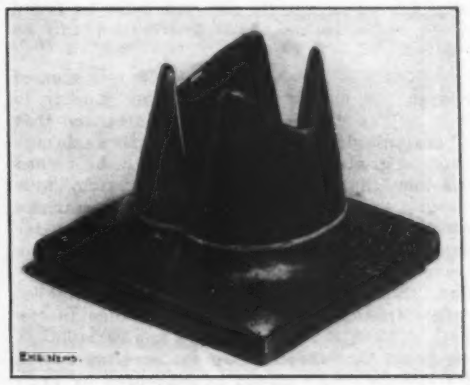

Fig. 2. "Model Method" of Representing Sewage Distribution, Based on Fig. 1.

so that the diverted liquid would fall upon its shoulder.

The loss of head in the piping between the stand-pipe and the nozzle orifice was measured and a pressure gage was arranged and calibrated, so that the effective head upon the nozzle orifice could be read at a glance with sufficient accuracy. An attachment was provided, causing an instantaneous cessation in the collection of the spray when the effective nozzle pressure reached a predetermined point. This feature was particularly valuable in the study of varying heads, where it was desired to limit, with precision, the minimum pressure. A general view of a discharging nozzle and the collecting gages is shown in Fig. 3. A wind shield, with roof, was provided, so that all results would be exactly comparable and free from irregularities arising from this source, the aim of the tests being to obtain the highest possible efficiency in aerial distribution in still air.

Methods and Results.

During the tests many questions arose which had never been solved, such as the following:

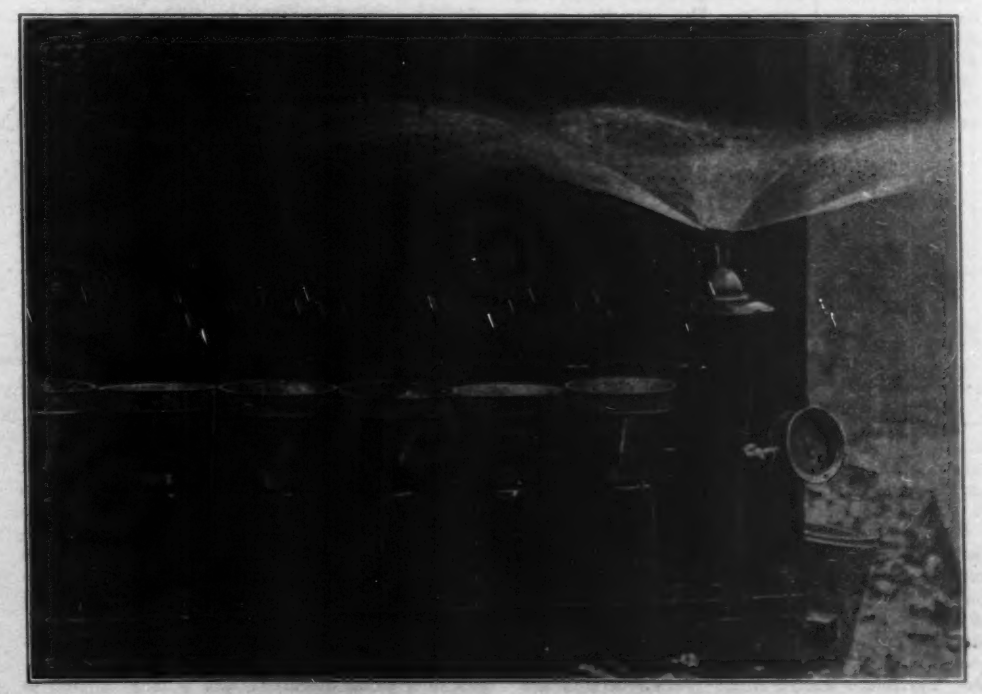

FIG. 3. GENERAL VIEW OF SEWAGE DISCHARGING NOZZLE AND COLLECTING GAGES.

With a sewage nozzle of any given type, what is the effect of a variation in the cone angle; what is the most desirable cone angle for a specific condition; what is the effect of a varying blade length on the diameter of the wet area and on the relative diffusion of the spray; where should the nozzle orifice be placed in relation to the filter surface, level with it or at some higher elevation; is it possible and practicable to cover the whole of a square area by a centrally fixed spraying nozzle; should the nozzle pressure be constant or variable, and if variable to what extent? These and many other vital questions arose for which correct answers must be found before perfection in aerial distribution can be attained.

VARIATION IN CONE ANGLES was studied through the use of spreading cones similar to Style A, Fig. 4, and they were so arranged that by beginning tests at the minimum angle the cone could, at the conclusion of each, be turned to a new and increased angle of elevation, thus reducing to a minimum the cost of the machine work. The cones were so formed that under each successive change in the cone angle the "travel distance," x to y, y_1, etc., remained constant, thus eliminating the unknown factor of surface friction and making the change in the angle of elevation of the jet the sole variable. It was found that theoretically the covering radius of a sewage nozzle should be influenced by variation in the jet angle as graphically shown in Fig. 5, when all friction losses are neglected.

In practice, however, sewage is rather viscous and there are necessarily considerable frictional losses in passing over the cone blade and through the air to the filter surface. Test cones, having angles of elevation varying by small increments from 10° depression to 52° elevation, were fully studied under nozzle pressures ranging from 1 ft. to 12 ft., these extreme limits, both as to angle and pressure, being well outside the limits met in practical construction. In a diagram, Fig. 6, is shown the actual effect of such variation in cone angle upon the diameter of the wet area in a full size, type M, sewage nozzle discharging in a practical way under a 12-ft. orifice pressure, with the orifice 6 ins. above the filter surface. In general form the actual and the theoretical curves agree, but they differ materially in detailed values.

At first a full nozzle test was made in triplicate for each foot of head from 1 to 12 inclusive, but it was soon found that such laborious operations were entirely unnecessary by reason of the perfection of the methods and the absolute uniformity of controlling conditions, which effected under duplicate tests, within very close limits, equivalent results. The collecting gages were 6 ins. in diameter, had thin edges, each presented a like area, and were held in alinement by a supporting rack. Under uniform distribution each collecting jar would receive the same volume of sewage in a given time.

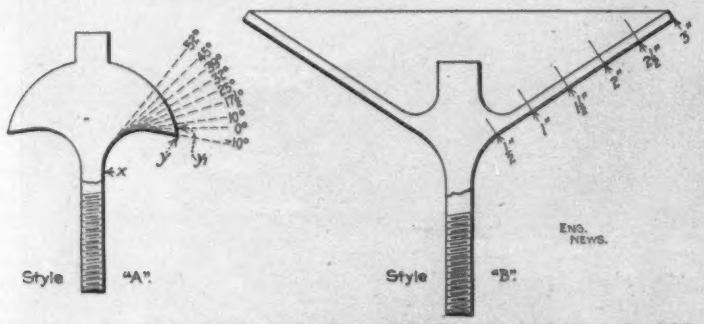

FIG. 4. SPECIAL SEWAGE NOZZLE CONES, STYLES A & B, FOR STUDYING VARIABLES.

Records were made of cubic centimeters collected and jar number, the said number also representing the diameter, in feet, of a circle passing through its center. Normally a test was of such duration as to admit the collection of 900 c. c. in the jar receiving the maximum dose, which was then designated as the diameter of the "maximum wetted ring." Jars receiving less than 0.5% of the mean were neglected and the number of the jar receiving a volume next greater was denoted as the "diameter of the wet area." These diameters, the maximum wetted ring and the wet area, were always sharply defined and constant under uniform conditions.

EFFECTIVE ORIFICE PRESSURE is an important factor in the performance of sewage nozzles, and any variation in it instantly affects the diameters of both the maximum wetted ring and the wet area. With a cone angle of 0° elevation the effect of such a variation, in terms of diameter of wet area and maximum wetted ring, is shown in detail in Fig. 7, for all heads between 1 and 12 ft., inclusive, and for three positions of the nozzle orifice, the term "f" designating the free height of the nozzle orifice above the filter surface. From these curves it is seen that with this angle of elevation, 0°, the diameters of the wet area, particularly, increase very rapidly from 0 to 4-ft. nozzle pressure, and that for each head above this there is a gradually decreasing increment. This fact held for all angles of depression, also angles of elevation less than about 17°. Above this elevation the curves flattened out in such a manner as to show that for each increase in nozzle pressure there is an almost direct arithmetical increase in the covering diameter.

In practical operation this feature is of material importance and any sewage nozzle not possessing it to a marked degree is at a decided disadvantage, because it fails to admit of a proportionate increase in its area of usefulness with each increase in effective head upon the orifice. Nozzles designed to cause a diffusion of spray over the whole of the definite area within their influence seem to have this defect, to a greater or lesser degree, as an inherent quality. Local nozzles designed upon the diffusion principle always exhibited this choking effect, which is also seen to a certain extent in the Birmingham, Salford and Columbus nozzles; but experiments showed that nozzles designed upon the opposite principle, that is to cover, under a constant head, a circumference or the periphery of a polygonal figure rather than an area, were markedly free from this defect.

The relative extent to which sewage nozzles, designed upon both of these basic covering principles, area and periphery, utilize the effective nozzle pressure active upon them is well shown in Fig. 8. The relative nozzle spacing of a Birmingham and a Columbus nozzle, both designed upon the area principle, may be taken at 2.10 and 2.23, respectively, for a 4-ft. nozzle pressure, and a type M nozzle, designed upon the periphery principle, may be taken at 2.70. A similar comparison may be made under a high head, say 12 ft., nozzle pressure, with the result that the relative nozzle spacings are as follows: Birmingham, 3.20; Columbus, 3.20; and type M, 4.90.

With all other things equal, the value of a sewage nozzle will vary with some function of its covering area, not in direct proportion, however, as may be at first thought, but at some greater rate. The covering area, assuming it to be a circle, in the above citation for a 12-ft. head, will have respective values equivalent to the square of the nozzle spacing, as follows: Birmingham, 10.24; Columbus, 10.24; and type M, 23.00. Hence it is seen that it is possible for a sewage nozzle based upon the peripheral principle to bring within its control more than twice the superficial area covered by excellent nozzles based upon the "area" principle when operated under precisely the same orifice pressure.

This distinguishing feature is of primal importance in its many practical bearings upon the subject now being discussed, and it may be well to briefly consider several: Any possible increase in the covering diameter of a sewage nozzle, under a definite pressure, directly increases the quantity of sewage to be discharged through its orifice within a given time, in proportion to the square of said diameters, with a resultant increase in the net area of the nozzle orifice, which in its

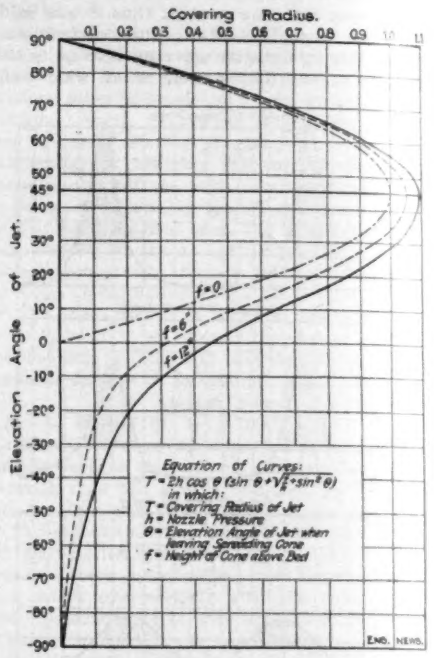
Covering Radius.
Elevation Angle of Jet.
f=0
f=6
f=12
Equation of Curves:
T = 2h cos θ (sin θ + √(½ + sin² θ))
in which:
T = Covering Radius of Jet
h = Nozzle Pressure
θ = Elevation Angle of Jet when leaving Spreading Cone
f = Height of Cone above Bed
ENG. NEWS.

Fig. 5. Theoretical Covering Radius of Sewage Nozzle as Influenced by Variation in Angle of Jet Elevation.

turn very greatly lessens if not entirely eliminates the clogging tendencies so common in the past; increasing the controlling area of a nozzle reduces the number of nozzles to be purchased, operated, and maintained; diminishes in a like manner the number of sewage nozzle-risers to be erected; lessens the total length of pressure mains and nozzle feeders and connections thereto, each of which is subject to the possibility of leakage; and lowers the cost of installation and operation and annual maintenance charges. These, among others, are essential qualities which are enhanced as the hydraulic properties of a sewage nozzle are improved.

ORIFICE ELEVATION concerns the question: With a definite working distance or total available head at the filter surface, what is the best disposition that can be made of this pressure; shall we place the nozzle orifice flush with the filter surface and thus have the full pressure effecting discharge and influencing the covering diameter or shall we find it advantageous to ele-

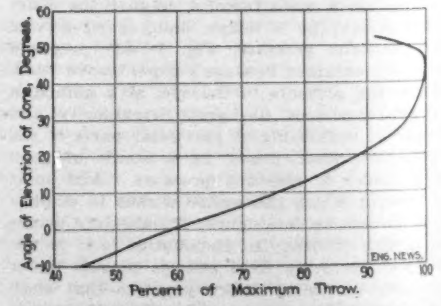

Fig. 6. Diagram Showing Actual Effect of Variation in Angle of Jet Elevation.
(Nozzle type M, cone A, 12-ft. head, f = 6 ins.)

vate the orifice to some point above the surface and there to operate the nozzle under a diminished pressure? The customary solution of this problem, as shown by works already constructed, is to place the nozzle at the filter surface and to operate with the total head, under the thought, doubtless, that the maximum covering area will

exist at such time as there is upon the nozzle the maximum available head.

This premise, however, is not necessarily a fact under all conditions, and therefore in general, particularly with nozzles based upon the peripheral covering principle, the most advantageous position of the nozzle orifice is at some point above the filter surface. The relative value of elevating the orifice level is shown in Fig. 9, in which two ratio curves are plotted, representing respectively the permissible nozzle spacing under effective heads ranging from 2 to 12 ft., for two positions of the nozzle orifice, 6 ins. and 12 ins. above the filter surface. It is seen that with type M nozzle, upon which the diagram is based, the permissible nozzle spacings for all values of working distance or total head above 3.2 ft. may be increased by raising the orifice to a level 6 ins. above the filter surface. With 6½ ft. total head above the filter surface the nozzle spacing may be increased 5% if the nozzle orifice is raised 6 ins. above the surface and operated under a 6-ft. head.

The full effect of any variation in free height of the orifice may be seen in detail for 0° cone angle in Fig. 7. The theory of the case is seen when we remember that the path of the sewage spray through the air, from the nozzle to the surface, is on an oblique line and often forms a very acute angle with the filter surface. Consequently, when the orifice level is raised the discharging velocity is reduced, but a greater covering diameter is effected for each increase in the free height, up to a certain maximum, by reason of the time gained for the travel of the spray along the hypotenuse of a very acute-angled triangle. Within the range of heads normally found practicable it is desirable to elevate the nozzle orifice to a point about 6 ins. above the filter surface.

EFFECT OF BLADE LENGTH upon the diameter of the wet area and upon the concentration of the sewage film was studied through the use of a cone, Style B, Fig. 4, which was so arranged as to permit, by sucessively reducing the diameter of the cone, a range of travel along the cone blade from 3 to ½ ins. The retarding influence of a blade length of 3 ins. over one of a ½-in. length was sufficient to reduce the diameter of the wet area from 10 to 15%, but the long blades developed the desirable feature of concentration of the sewage spray into a narrow zone, on much the same principle that a long-barreled shot-gun causes concentration of the shot. Giving both factors proper weight, the optimum advantage seems to exist when the blade length for circular cones is about 1¾ ins., with a corresponding cone diameter of about 2½ ins.

JET VS. CONE ANGLE.—A film of sewage departing from a carefully-molded spreading cone, designed for the concentration of the spray, does not, under most conditions, follow through the air a path having an angle of elevation coincident with the cone blade or tangent to the terminal point of a curve thereon, but tends, instead, to travel along a somewhat greater angle of elevation. The reason for this is, probably, that the sewage film as it passes up the spreading cone has a gradually decreasing thickness due to the increasing diameter of the cone, with the consequence that the angle of elevation of the lower film-surface is a little greater than that of the cone blade; and, further, the velocity of the film-surface in contact with the cone is slightly less than that in contact with the air. These two factors—nonparallel film-surfaces and unequal surface velocities—cause the jet angle to leave the cone blade along the path of the resultant of the two converging forces.

Two practicable methods have been found to measure this superelevation of the jet: (1) by piercing the film with two parallel, spaced apart, needle-pointed, steel pins, based upon the principle of the Hooke gage; and (2) by means of a photographic plate exposed from a distance through a telephoto lens. Both methods were found to be accurate and each best suited for a particular range of cone angles. Plotting the values so measured, it was found that the points for a given cone angle lay along a clearly defined parabolic curve, and that the amount of superelevation became greater as the nozzle pressure was increased. An idea of the extent of the superelevation may be had by defining the values found for a 17½° cone angle; 1-ft. orifice pressure, 1° 27′; 2-ft., 1° 52′; 4-ft., 2° 30′; 6-ft. 3° 00′; 8-ft., 3° 24′; 10-ft., 3° 43′; 12-ft., 4° 0′.

VARIATION IN NOZZLE PRESSURE has a profound effect, for good or ill, upon the uniformity of distribution. With the apparatus described it was possible to test the distribution of a nozzle when actuated, throughout its cycle, by a varying head made to follow any predetermined curve, and it was through this means that it was found possible to distribute sewage over percolating filters by fixed nozzles with a much greater degree of uniformity than had before been accomplished.

The distribution effected by a Birmingham nozzle, which represents, perhaps, the highest practicable efficiency of a sewage nozzle designed to cover an "area" when operated under a constant head, is shown by line "D" in Fig. 10. In this figure the abscissa represents diameter of the surface area, in feet, and ordinates the percentage of mean rate, and it will be noticed that absolute perfection in distribution would be represented by a straight line coincident with the ordinate line marked "100 per cent. of mean rate." On this basis curve "D" shows that the Birmingham nozzle, tested under 8-ft. constant orifice pressure, with a free height of 6 ins., had a wet area and a maximum wetted ring having diameters of 17 ft. and 9 ft., respectively; that the surface area within the zone of the maximum wetted ring received sewage at a rate of 218% of the mean; that the zone lying between circles having diameters of 13 and 17 ft. was underdosed; likewise a central circle having a diameter of 5 ft.; that the residue of the surface area, which lies in a zone between the diameters of 5 and 13 ft., is overdosed.

The very uneven distribution of the old-style Salford nozzle is shown in curve "B" in the same figure, the plotting being based upon data gathered by Gage in the Lawrence tests. It is seen that the rate of dosing increases very rapidly from the center of the controlled area to the diameter of the maximum wetted ring, at which point the sewage is applied at a rate of 600% of the mean, and then as rapidly diminishes to the extreme diameter of the wet area. A glance at the diagram is sufficient to show that the difference in real efficiency and practical usefulness of these two nozzles is very great.

Line "C" represents the distribution effected by a type M nozzle, having a 32½° cone angle,

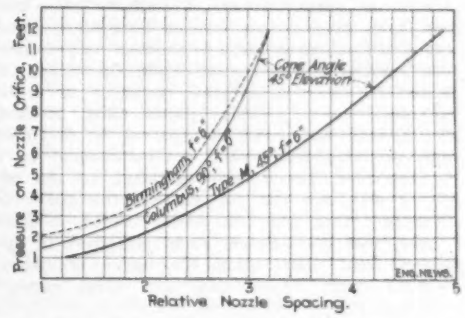

Fig. 8. Effect of Varying Nozzle Pressure Upon Nozzle Spacing.

(Nozzle spacing equals the mean between the diameter of wet area and diameter of maximum wetted ring.)

a 2-in. blade length, and a free height of 6 ins., and actuated under an 8-ft. constant orifice pressure. This nozzle is based upon the principle of the concentration of the sewage upon an outer zone, and the excellence of the hydraulic qualities of the nozzle is shown by the position of the wet area at 21-ft. diameter, and this with a cone angle giving a lesser throw than the maximum. Under these conditions the maximum wetted ring has a diameter of 15 ft. and the dose applied upon this ring is 390% of the mean. The amount of discharged sewage, both beyond and within the maximum wetted ring, decreases very rapidly, and the plotted rate of variation from the maximum to zero, on either side, practically follows a straight line. Sewage thus discharged would pile up, if a sectional model of distribution were to be made, on the surface of the filter in the form of a high, acute-angled triangle.

Low efficiency in uniformity of distribution results from such a nozzle under fixed-head conditions, but from an examination of the curve "C" it is readily conceived that through a precise overlapping of an adjacent spray so that a point near the extreme wet area, y, of one nozzle shall coincide with the maximum wetted ring, x, of the other in such a manner as to produce a uniform application between the points x-x, as shown by the dotted line, it is possible to equalize the distribution over this outer zone. And further it is theoretically possible, through a correct reduction in the orifice pressure, to cause the crest point, x, to travel inward along a level plane until the center is reached, thus producing absolute uniformity of distribution across the full diameter.

CYCLIC PRESSURE VARIATION on a sewage nozzle has a wonderful influence on the character of the sewage spray and the resultant uniformity of distribution. Literature is practically barren of data concerning studies having a view to the betterment of sewage distribution through a control of the nozzle pressure, and

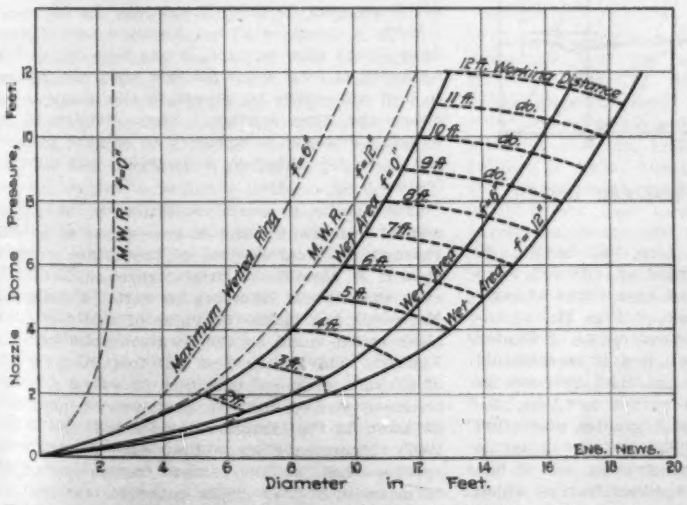

FIG. 7. DIAGRAM SHOWING EFFECT OF VARYING NOZZLE PRESSURE ON DIAMETER OF WET AREA.

(Cone angle 0°; f = 0, 6 and 12 ins.)

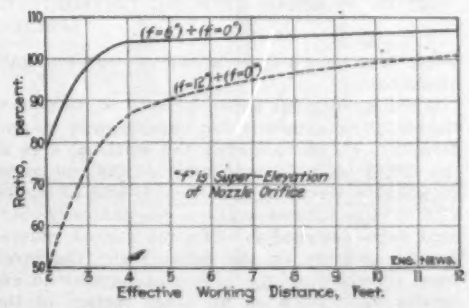

Fig. 9. Effect of Elevation of Nozzle Orifice Upon Nozzle Spacing.

those tests that have been published have dealt principally with such variation in pressure as was obtained through the discharge of a vertical-sided dosing tank, e. g., those at Lawrence (Eng. News, Aug. 20, '08, p. 203, and 39th Rep. Mass. St. Bd. of H., 1907, p. 203) and the Massachusetts Institute of Technology (Tech. Qr. 20,-369, Sept., 1907), and such variation as might be obtained through the successive hand throttling, by small increments, of a gate valve placed on the main influent.

Ordinary dosing tanks, of uniform cross-section, have been shown, by the tests above cited and those at Waterbury, to produce very imperfect results, and we must look, therefore, for means to effect a correct variation in cyclic pressure. In a previous paper (Eng. Record, Jan. 5, 1907) the writer emphasized the fact that uniform distribution could not be effected by a vertical-sided dosing-tank operating in the ordinary way, for the reason that the curve of pressure acting upon the nozzle orifice, in such a case, was of improper form and that to approach ideal distribution the curve of nozzle pressure must approximate an "ideal curve," which was known to be a complex curve of parabolic form.

When writing the paper referred to, two practicable ways appeared for improvement in uniformity: (1) so to modify the sectional area of the dosing-tank, by tapering, that the true curve of pressure would be approached; and (2) to insert in the influent main a mechanically-operated valve designed to effect the desired undulation in pressure on the outlet port. Discharge from a vertical-sided dosing-tank permits an excessive application on an inner portion of the dosed area, and the relative rate of overdosing sharply increases as the center of the area is approached; this feature is clearly shown by line "A" in Fig. 10.

There are three general methods available for the regulation of the nozzle pressure, and their relative value, beginning with the least efficient, is in the order named: (1) Hand throttling; (2) tapered dosing tanks; (3) mechanically-controlled pressure valves.

Hand throttling involves the frequent setting of a hand-operated valve at specific openings, so that through successive adjustments the nozzle pressure is gradually increased by easy steps from minimum to maximum, or the reverse. The whole method, however, is so entirely impracticable and so utterly insufficient to effect a proper operation of large filters under working conditions that it will not be discussed in detail.

Tapered dosing tanks are simple in construction, and if the molded sides are correctly designed an excellent distribution is theoretically possible for all portions of the filter surface within the range of the nozzle under the maximum and minimum heads. These dosing tanks are particularly adapted for small and isolated filters.

Mechanically-controlled pressure valves represent the highest type of apparatus yet proposed for the regulation of the effective nozzle pressure. The type is particularly adapted to all plants where the highest possible efficiency is essential. Local studies for the development of the true curve for the variation in nozzle pressure have resulted in delineation of the curve shown in Fig. 11. Fulfilment of the pressure conditions prescribed by the curve upon the orifice of a type M nozzle, designed on the principle of peripheral dosing, produces a practically perfect distribution of sewage across the diam-

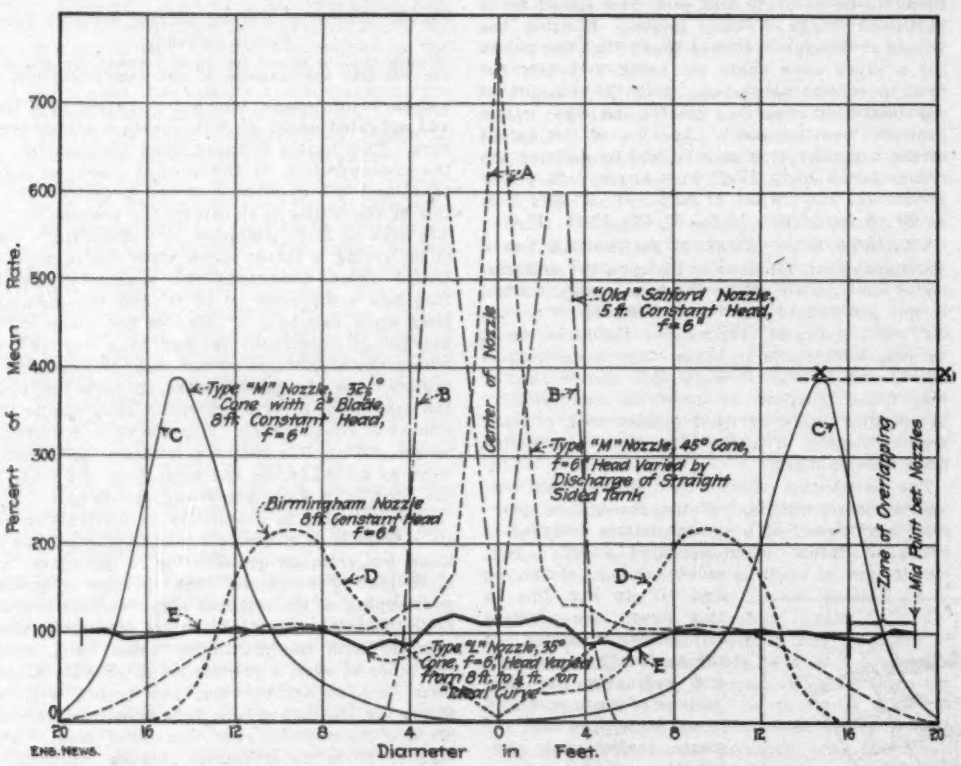

FIG. 10. DIAGRAM SHOWING DISTRIBUTION EFFECTED BY SEVERAL NOZZLES UNDER SPECIFIC CONDITIONS.

eter of the wetted area. Line "E" in Fig. 10 represents the actual distribution effected by a type L nozzle when actuated by a curve of pressure closely resembling that of Fig. 11.

The uniformity of distribution as indicated by line "E" is almost ideal, and it is certainly sufficiently perfect for the practical purposes of sewage purification. Other curves could be presented which represent a still greater perfection in distribution than line "E," but the latter is sufficiently perfect for demonstration, and it has the advantage of showing a minor feature which modifies the pressure curve to some extent. At 6-ft. diameter a slight depression is noticed on the distribution curve "E" and a slight crest at 2-ft. diameter; these are caused by a modification in the form of the discharging jet which takes place when a particular point in the nozzle pressure is reached; a very little change in the pressure curve is sufficient to practically eliminate the irregularity.

SUMMARIZING THE TESTS, certain important features are to be found which are new; others are put forth with greater emphasis than heretofore, and there are still others whose influence should be restrained. Each of these factors is helpful in the struggle to acquire the maximum in either quantity or quality of filtrate per unit area of exposed bacterial surface within the filter material.

In approaching the problem all thought of effecting a material betterment in the diffusion of the influent through subsurface or lateral flow within the filter volume must be abandoned; likewise any dependence upon the wind for the performance of efficient duty. The elimination of these factors throws upon the fixed nozzle the desideratum of effecting, in still air, perfection in *aerial distribution.*

An important step was taken toward the solution of the problem when all attempts to cover simultaneously the whole of the controlled area were abandoned and efforts were directed upon the concentration of the influent spray upon the narrowest possible zone. The recognition of the relative values of these two diffusion principles—areal vs. peripheral—has done much toward making possible a high degree of uniformity in sewage distribution from fixed nozzles.

The positive and calculable influence of the angle of elevation of the discharging jet, the length of the cone blade, and effective orifice pressure upon the performance of a sewage nozzle makes it practicable to proportion the structural details of a nozzle so as to obtain, within narrow limits, any desired diameter of wet area or of maximum wetted ring. And an appreciation of the influence of variations in these structural features has led, through the application of the principles of gunnery, to marked success in the covering of square, hexagonal and other polygonal areas through special conformation of the spreading cone.

For covering square areas, the molded cone, having a proper contour, is provided with four lobes, so arranged that a drop of sewage traveling along a quadrant axis, with a definite velocity, leaves the spreading cone along the maximum angle of jet elevation, Fig. 12, and falls at the intersection of the periphery and a short diameter. Midway between the quadrant axes, at the intersection of the lobes, passing drops have a like velocity with those traveling along the quadrant axes, but are given the maximum angle of jet elevation, which causes a greater traveling distance, with the result that the drops fall at the intersection of the periphery and the diagonal. Intermediate points on the periphery are covered by drops leaving the lobe edges at corresponding points. In a similar manner hexagonal or other areas may be covered.

With a fixed working distance, or effective head at the filter surface, it has been shown that normally at least 6 ins. of this head can be used to best advantage by elevating the nozzle orifice above the filter surface. Such division of the working distance is contrary to current practise, but it is, nevertheless, a desirable and valuable feature.

True cyclic pressure variation is of fundamental importance, and it now seems to be only through an ideal control of the orifice pressure that it is possible to attain, through fixed nozzles, the highest efficiency in aerial distribution. No words can make the value of this feature as clear to the mind as the diagrammatic drawing, Fig. 10. The writer first put forth the thought of a cyclic pressure variation following a predetermined curve, and the peripheral principle of diffusion, in the "Engineering Record" for Jan. 5, 1907. Experience since that date confirms the opinion that in these two factors—peripheral diffusion and true cyclic pressure variation—is the "open sesame" to the problem of sewage distribution by fixed nozzles.

Apparatus Development.

Studies, as briefly outlined, have led through a gradual evolution to the development of a particular type of fixed nozzle, a sewage riser and a valve to effect, in a very simple and positive manner, any desired variation in cyclic pressure. Each of these pieces of special apparatus differs radically as to basic principles, materials and form of construction from devices heretofore used or proposed, and although the departures from current practice are wide, yet each feature is rationally based upon a foundation of fact as

revealed by a close study of the Waterbury experiments.

THE SEWAGE NOZZLE now in most favor is shown in Fig. 12 and consists essentially of two pieces—a nozzle dome and a spreading cone—each of which is made from material particularly suited to the use to which the part is to be applied. The nozzle dome is circular in transverse section, has a thin shell and is comparatively light in weight, although it has abundant strength for stability and utility. A central hub, supported internally by two legs, is tapped to receive and to support the spreading cone in a vertical position. A discharging orifice is drilled and reamed to true diameter in the nose of the

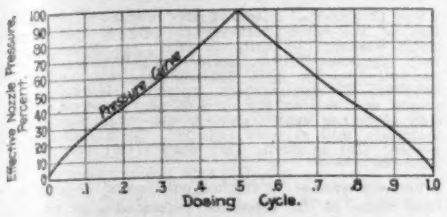

Fig. 11. "Ideal Curve" Showing Pressure Variation Throughout Dosing Cycle.

nozzle so as to be concentric with the tapping in the central hub. Through this orifice the cone spindle enters and a threaded portion on it engages in the tapping of the central hub, and by means of an enlargement in the central third of the cone spindle a micrometer adjustment of the nozzle orifice is arranged so that in practice any desired net area of discharging jet, from maximum to zero, may be readily obtained and secured against subsequent change by means of a check-nut on the spindle below the central hub.

The lower exterior part of the nozzle-dome is machined to a taper of 1 in 50 and made to precisely fit a standard gage. Above the tapered space are two cylindrical lifting lugs, diametrically placed on the nozzle-dome, by means of which the nozzle is readily lifted from its socket in the riser through the use of a small, two-fingered, yoked hand lever.

The spreading cone shown in the figure is based on the peripheral-covering principle, has a carefully contoured and polished water-contact surface, and four lobes which provide a sufficient range in the angle of jet elevation to cause the sewage to be diffused over the periphery of a square. Other cones may be substituted having suitable shapes to cause the control of hexagonal, circular, triangular or other polygonal areas. The nozzle and spreading cone illustrated is designed solely for use under an intermittent and a properly controlled cyclic variation in nozzle pressure and would not be suitable at all for constant operation under a uniform head.

The water-way through the nozzle is large, smooth and free, consequently the hydraulic properties are excellent and the discharging coefficient high. Clogging of the nozzle is impossible when the sewage has been given a reasonable preliminary treatment, and it is fully capable of diffusing over the surface of a percolating filter any liquid that is in a suitable physical condition to be so discharged. These non-clogging qualities reduce to a minimum the nozzle-maintenance charges. At infrequent intervals it is necessary to remove each nozzle from the riser for the purpose of freeing its interior from fungoid growths which always develop upon surfaces in contact with sewage. This cleaning is quickly accomplished by an ordinary workman as follows: hold the yoked lifting lever in the left hand and insert its fingers beneath the lifting lugs, and press down until the dome is extracted from the riser socket; then grasp the nozzle dome and spreading cone firmly with the right hand and make one strong, quick, full-arm swing and the centrifugal force developed will free the nozzle from excessive growths or foreign matter; another motion inserts nozzle in the riser and a tap completes the operation.

Many metals and certain non-metals are suited, in a general way, for nozzle construction. The combination of a yellow-brass nozzle-dome and a high-grade bronze spreading cone has advantages to commend it, although it has on the other hand some unfavorable features, among which may be found the readiness with which the metals may be junked by thieves. At many works this is not, fortunately, a leading feature, but it may be entirely offset through the use of certain alloys from which it is entirely practicable to make the nozzles. One suitable set of alloys is the copper-nickel-iron class, which has, when scientifically proportioned, very great resistance against acids and alkalies and corrosion in general, and at the same time has an elastic limit and tensile strength above that of structural steel. The polished portions appear to be nickel plated and the unpolished portions have the general appearance of cast-iron. These alloys are unusual, and under normal conditions could not be junked.

Orientation of nozzles covering geometrical figures must be simply and definitely provided for, as it is evident, for instance, that a misplaced square-spray nozzle would cause a highly improper overlapping. Perfect orientation may at all times be maintained, even by ordinary workmen, if a simple system is adopted and adhered to; for example, when the nozzle orifices are calibrated or installed, the cone notches should be turned so as to have a constant relationship with the lifting lugs on the dome and then firmly secured in this position by a checknut on the spindle. Previous to the insertion of the nozzles into the risers a string should be stretched over each feeder line and its axis plainly marked upon the top of each riser by a V notch. After this, perfect orientation, certainly within a degree, can be positively and quickly obtained by simply dropping the nozzle into the riser socket so that either one of the lifting lugs is directly over the V notch.

SEWAGE RISERS have almost universally been made of iron, generally cast-iron, although lap-welded pipes have sometimes been used. The latter are subject to rapid corrosion and the former, in many cases, to marked tuberculation. Cast-iron risers for sewage nozzles have certain inherent defects, among which may be mentioned corrosion with ever-increasing interior roughness, excessive loss of pressure head, conditions favoring rapid growth of filamentous fungi, impracticability of obtaining a nozzle attachment other than by screw-thread, inflexibility as to vertical height, and high cost.

Efforts to overcome the defects of cast-iron without creating new difficulties have resulted in development of the new type of nozzle riser shown in Fig. 12, which is manufactured of tough fiber prepared for use by impregnation with mineral bitumen and baking. The resultant material has the general appearance of hard-rubber, is light, durable, and sufficiently hard. Its non-corrosive qualities are well emphasized by the fact that tubes of this material have carried sulphuric acid at 175° F. for a period of over eight years without injury. Internally the riser is very smooth, has low friction factors, presents the minimum opportunity for the accumulation of slime and fungoid growths and permits a ready removal of such growths, with the restoration of the interior surface to its original condition, by the simple passage of a slender flue brush.

The resilient qualities of the above new material make possible and practicable the application of the ideal mode of attaching a sewage nozzle to its riser—by a simple taper. And this tapered attachment is positive and ample, for tests made with blank plugs have shown that, without excessive driving of the plugs into place, there is ability to withstand a total pressure of 60 lbs. per sq. in. or an amount equivalent to 40 lbs. thrust per sq. in. of contact surface. From this it is seen that a very light tapping of the nozzle-dome is sufficient, in actual practice, to make the nozzle secure against the light pressures there in service.

A removable nozzle-tip screwing into the riser pipe ensures against maltreatment on the part of attendants, and should injury occur to the exposed portion of the riser a new tip may, at any time, be inserted.

A drip bib, fitting the outside tapered space of the sewage riser, is so driven as to grip firmly the removable nozzle-tip near its top. This flanged metallic ring is designed to fulfil dual purposes: (1) the band reinforces the nozzle-tip and takes up all excessive circumferential stresses developed through the wedging action of the nozzle-dome; and (2) it intercepts all unfiltered sewage and obviates its possible travel along the sewage riser to the drainage system, by discharging such descending film upon the filter material beyond the riser.

Another desirable feature, although of minor importance, is the ability to cut each riser to exact length as measured at the site of the work, and thus secure an accurate grade alinement of nozzles. Such adjustment is impracticable with cast-iron risers, consequently any irregularity in the dimensions of a vitrified-pipe tee or other special in the feeder-main, if such are used, or the carelessness of a laborer in placing a hub socket, leaves a permanent defect in the nozzle alinement when cast-iron risers are used.

Frequently brass screw-threads in contact with iron are removed only with difficulty. In such cases the nozzle can be started from a cast-iron riser only through the use of two stout and powerful wrenches, and it is entirely possible under practical operation, through carelessness on the part of a workman or the slipping of a wrench, so to twist the cast-iron riser as to cause permanent leakage of unfiltered sewage at the base joint. Tapered nozzle connections entirely obviate the possibility of such leakage.

All joint materials such as have been successfully used with cast-iron risers may be used with those of bituminized fiber, and any of the following will be found satisfactory; molten lead or lead wool, sulphur or sulphur and sand, and stiff bituminous compounds, although the writer prefers the last-named for general use.

In designing sewage-nozzle risers we meet two principal governing conditions; one, that of first cost, tends toward the selection of small diameters with high velocities; the other, conservation of the pressure head, tends toward larger diameters and lesser velocities. The optimum diameter exists between these two, and its position varies with the material to be used in the

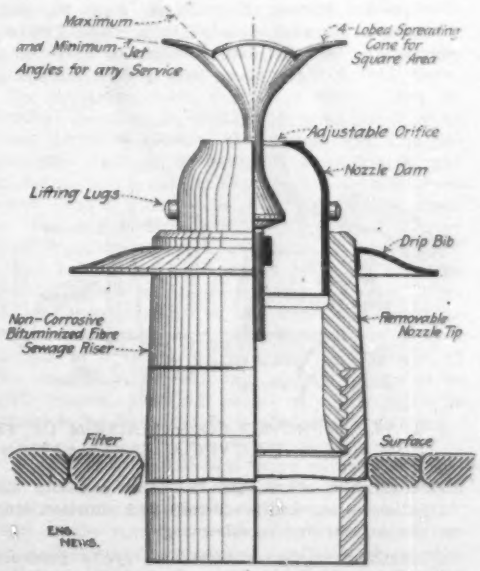

Fig. 12. Taylor Nozzle and Riser (Patents Pending).

riser. It is a mistake to permit an enlargement of the riser near its top for any reason, as the enlargement causes a marked reduction in the vertical velocity through this section, thus affording most favorable conditions for the rapid growth of filamentous matter. The fiber riser permits a lesser diameter than one of cast-iron for the same loss of head, thereby making economical a somewhat greater velocity, and affords a mode of attachment that obviates any enlargement or material change in the sectional area—all of said factors tending toward the minimum opportunity for fungoid growths.

And lastly may be mentioned the advantage of the lessened first cost of the bituminized sewage riser.

PRESSURE UNDULATING VALVES for producing cyclic variations in effective orifice pressure in sewage nozzles, to be applicable to general use in municipal works, ought to have characteristics of such a nature that the apparatus as a whole is positive in action and extremely simple in structural detail, in both the pressure controlling and the actuating parts. Non-clogging qualities are essential; consequently, in working with such foul liquids as sewage, accessibility to every part for inspection and cleaning becomes of paramount importance. The applica-

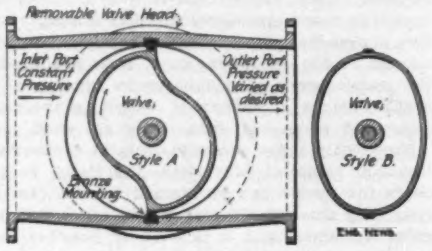

Fig. 13. Taylor Pressure Undulating Valve (Patents Pending).

tion of mechanical force to such ought to be by rotation and not by reciprocation, and the motion in the actuating device, at least, ought to be uniform and constant, although intermittency in the pressure-controlling parts is permissible under certain favorable conditions. Pressure upon the inlet port of the valve should be constant and the pressure upon the outlet port should vary from maximum to minimum exactly in accordance with a predetermined curve representing the true cyclic variation for the particular case, e. g., see Fig. 11.

Provision should also be made for modifications in the dosing rate, so that a filter normally operated in mid-summer at a daily rate of 3,000,000 gals. per acre when conditions are most favorable for intense bacterial activity and the acceleration of interstitial aeration (see Taylor on Aeration of Percolating Filters, Eng. News, Aug. 19, 1909) may have its rate reduced to perhaps 2,000,000 during the late fall, and possibly to 1,500,000 or even 1,000,000 for open beds during periods of extreme cold, when the bacterial capacity for oxidation is markedly reduced and aeration may not be accelerated to advantage.

Throttling of the influent and cyclic pressure variation may be attained through the use of a variety of apparatus, such as gate valves, graduated orifices, butterfly valves and the like. Each of these and other methods have been carefully studied, with the result that a summation of the desirable and essential features for an undulating valve were not found in any of the above-named types. Finally, however, a new type of pressure controlling valve was created (Fig. 13) which eliminates the mechanical difficulties appendant to other types of pressure undulating valves as now known, and which seems to be in every particular eminently suited to sewage work.

The new valve consists essentially of a cylindrical or rectangular throat, within which is placed a rotable valve platen having such specific sectional contour that it will produce, as a result of its rotation, a variation in pressure at the outlet port that will precisely follow a predetermined cyclic pressure curve. The actuating apparatus is as simple and as positive as the pressure control and consists essentially of a small, low-speed, standard motor of any desired type, with a single train of encased reduction gears—all of which may be attached by brackets to the valve head or mounted on an independent pedestal. As shown by Fig. 13, the valve is extremely simple and positive in action. So long as the valve is rotated the true cyclic pressure variation must be followed and the influent applied at the correct rate. Variation in the speed of rotation does not modify the effective filter rate or change the form of pressure curve, but simply alters the length of the dosing cycle.

On each of the vertical side-faces of the valve is placed a circular valve-head, and the removal of either will permit an examination of the interior or the removal of the sole rotating part—the valve platen.

Any desired dosing requirement may be met in this undulating valve and any mode of cyclic dosing followed; that is, the nozzle system may start spraying under the minimum head, the pressure increasing to the maximum at the ½-cycle point and then following the reverse during the remaining half cycle; or the nozzles may start spraying under the minimum head, the pressure increasing until the maximum is reached at the end of the cycle, when the flow ceases abruptly; or the cycle mode may be as otherwise desired. Not only are the cycles under perfect control, but the true filter rate as well.

Pressure-undulating valves of this character may be direct-connected and driven singly or coupled up and driven in sets by a single motor. A typical installation, and one similar to that proposed for Waterbury, is shown in Fig. 14. The main influent is of reinforced concrete, runs along the head of the filters, and is provided at proper intervals with filter influent connections. The details of the connections between the influent main and the nozzle distribution system are so clearly shown in the illustration that further description is not required.

In conclusion, it should be stated that the experiments and studies herein briefly outlined have been a part of the investigations made by the city of Waterbury in its efforts to solve its particular sewage problem, and that the studies have been generously fostered by the Board of Public Works, with Mr. R. A. Cairns, M. Am. Soc. C. E., as City Engineer, and the writer in direct charge of the experimentation, design and construction of the works.

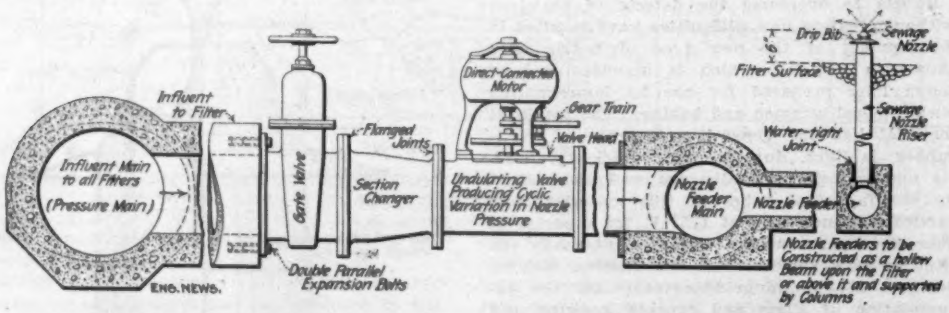

FIG. 14. IMPROVED CONSTRUCTION OF PERCOLATING FILTER DISTRIBUTION SYSTEMS, WITH TYPICAL INSTALLATION OF PRESSURE UNDULATING VALVE.

THE GENERAL MANUFACTURERS SCHEDULE, to be issued by the U. S. Bureau of the Census in collecting statistics on manufacturing for the calendar year 1900, has been formulated and some 700,000 copies have been ordered printed. The schedule was prepared chiefly by Mr. E. Dana Durand, Director; Mr. William F. Willoughby, Assistant Director, and Mr. William M. Steuart, Chief Statistician for Manufactures. As stated and commented on editorially elsewhere in this issue, the schedule has been simplified as compared with earlier ones. Notwithstanding this, some important lines of inquiry have been added. One of these calls for the name of the stream or lake from which water is taken to generate power for use in manufactures. The census authorities state that the information which it expects to obtain in this way

will furnish a first step toward a census of the country's water-power plants and operations should Congress specifically authorize such a census in the future.

Another new line of inquiry calls for information regarding the quantity of various kinds of fuel used. Shortly after Jan. 1, 1910, the schedule will be distributed among the manufacturers of the country by means of some 1,600 special agents, to be appointed as the result of test examinations held on Nov. 3, 1909. Attention is called on the printed schedule to the fact that every manufacturer is required by law to furnish the information requested, but it is stated that this information will be held absolutely confidential, and that no names of individual establishments will be disclosed in the publications of the Bureau. The general line of inquiry is thus summarized by the Bureau:

The 13 principal questions are, briefly: (1) a description of the establishment; (2) time in operation and hours worked; (3) capital invested; (4) salaried employees; (5) wage-earners, including pieceworkers, on the pay-roll Dec. 15, 1909, distinguishing men, women and children; (6) wage-earners, including pieceworkers, employed on the 15th day of each month, without distinction of sex or age; (7) salary and wage payments; (8) materials, mill supplies and fuel; (9) miscellaneous expenses; (10) products; (11) power; (12) fuel, and (13) remarks.

Those interested in further details will be able to secure copies of the schedule, we presume, by addressing the Director of the Census, Washington, D. C.

THE CORROSION OF WATER PIPES in some cities of the Middle West, with particular reference to corrosion at St. Louis since the new system of water coagulation and sedimentation was put into effect, was investigated not long ago by Prof. Earle B. Phelps, Assoc. Am. Soc. C. E., of the Massachusetts Institute of Technology (also of 30 Church St., New York City). The investigation was made for the Sanitary Committee of the National Association of Master Plumbers, of which Mr. David Craig, of Boston, is Chairman. Professor Phelps' report is published in the report of the committee just named for the year 1907-08-09. The sale and distribution of this report is in the hands of Mr. Walter D. Nolan, 721 14th St., N. W., Washington, D. C. We quote from the report Professor Phelps' conclusions, as follows:

The waters of the Mississippi River after purification at the water-works of St. Louis are exceedingly corrosive for galvanized iron pipe. This corrosive action has been more noticeable since the introduction of the present system of purification by means of iron sulphate and lime. Similar treatments of waters elsewhere, where either sulphate of iron or sulphate of alumina (alum) are used, have in many cases resulted in increasing the corrosive action of those waters.

The only essential change in the chemical character of the water in question due to treatment, is the removal of a large portion of the carbonate ions and the substitution of sulphate ions in their place. Chemically considered, the water is not rendered more corrosive for zinc by this change.

In the presence of electrolytic action, however, sulphate ions tend to attack and dissolve the zinc, while carbonate ions protect it.

Very weak electrolytic action is always present when dissimilar metals are in contact with each other and both in contact with a solution containing such salts as are found in this water. Such action is particularly noticeable when the metals are zinc and copper or zinc and brass. Where copper or brass fittings or hot water pipes are employed in the neighborhood of galvanized iron pipes the water in question is bound to set up electrolytic action with the consequent corrosion of the zinc.

No sanitary question is here involved.

The remedy in the particular case of St. Louis lies in the substitution of lead pipe for the galvanized iron pipe now employed. Tin lined or other protected pipes may serve equally well. The water will not have any serious solvent action upon the lead if the specimen analyses submitted are representative. Before making any radical changes, however, this point should be more carefully studied.

A 14-IN. GUN FOR BATTLESHIPS is now under construction at the Washington Navy Yard. Press reports regarding its details are as follows.

The gun will weigh 63.3 tons, or ten tons more than the 12-in. guns of .45 caliber length built for the battleships "North Dakota" and "Delaware," and about six tons heavier than the latest type of .50-caliber-length 12-in. guns intended for the "Arkansas" and "Wyoming." Its total length will be 53½ ft. The capacity of the chamber of the new gun will be 15,848 cu. ins., that being the compartment in which will be placed the charge of 365 lbs. of smokeless powder required to discharge the powerful projectile, weighing 1,400 lbs., which the gun will fire.

This gun will have an extreme range of more than 25 miles, although the range at which it would be fired in actual battle would be about five miles. The shell from this new gun will leave the muzzle of the weapon at the rate of 2,000 ft. a sec., and its muzzle energy will be 65,606 ft.-tons. This is about 13,000 more foot-tons of muzzle energy than that designed for the latest 12-in. guns, and about 22,000 ft.-tons more than that of the .45-caliber-length 12-in. guns now in service. So great is the penetrative power of this new gun that when fired with a full charge of 365 lbs. of powder, the projectile would penetrate 22.7 ins. of the latest Krupp steel armor at the muzzle.

After the shot from the 14-in. gun has traveled a distance of 3,000 yds. it will still have a remaining velocity of 2,234 ft. a second, which would enable it to pierce at that distance a thickness of 18.7 ins. of Krupp steel armor.

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In another part of this issue the principal apparatus of a single-phase line for heavy railroading in Switzerland is described as it existed at the completion of the development period, in July. The concerns interested have expressed their approval of the designs evolved and their readiness to equip other lines with similar apparatus, so that in a sense these designs are the latest word on heavy electric traction in that part of Europe at least. We believe that much of the construction described and pictured will be examined with interest in this country. There are, of course, many points in strong contrast to the tendencies of heavy electric traction, or even of single-phase traction, in this country. This is perhaps most notable in the two types of locomotives described.

It will be seen that the design of the Swiss company retains the use of parallel rods between driving wheels, continuing the practice noticed in the Valtellina and Simplon railways.* The use of parallel rods in this country on electric locomotives can hardly be called more than experimental, even noting the design of the new locomotives for the Pennsylvania Railroad's New York tunnels, also described in this issue. The German design, used on part of the Seebach-Wettingen line is more familiar to American eyes as a piece of electrical apparatus than the Swiss.

It will be surprising to many that one American development has found no counterpart on this experimental line, where the problems of heavy mountain traffic have been studied for some seven years. We refer to the "articulated-truck" type, where all the driving and buffing stresses are borne by two heavy coupled trucks and are not transmitted through the center pins to the cab frame at all. The upper work can thus be made very light, as it has only to carry the auxiliary apparatus.† The nearest approach to this in the locomotives used on the Seebach-Wettingen line, is in the German design, where the end frames of the trucks carry the couplers and buffers. But instead of transmitting the stresses directly from truck to truck, through a knuckle coupling, a section of the cab frame, between the truck pivots, is made to serve as the link between trucks.

A glance at the general design of the new Pennsylvania electric locomotive will please the old friends of the steam engine, for they will see embodied in the new machine many features made familiar by long use on steam locomotives. Indeed, to a casual observer the new engine looks as though two American-type steam locomotives without their tenders had been coupled back to back, the cylinders knocked off, the connecting rods turned back and up into the cabs which in turn had been built out to cover up the boilers. It is noteworthy that the specifications for the details of running gear with few exceptions reflect the present steam locomotive practice of the Pennsylvania.

*Engineering News, 1905, Jan.-June, p. 461; 1906, July-Dec., p. 562; 1909, July-Dec., p. 100.
†Engineering News, 1909, Jan.-June, p. 700. July-Dec., pp. 16 and 378.

We are glad to see that the new Director of the U. S. Census is reframing some of his schedules so as to exclude questions to which it is impracticable, if not impossible, to give correct answers. The specific instance which we have in mind relates to manufacturers' schedules. These schedules for the years 1900 and 1905 called for very detailed classification and averages of the wages paid employees, by sex and age. Strict accuracy would have required that either the special agent or the manufacturer should make a careful analysis of each pay-roll throughout the year, "usually either 52 or 26 in number, counting the number of men, women and children separately on each." In announcing his changes in the manufacturers' schedule, Mr. E. Dana Durand, the new Director, stated:

> As a matter of fact, practically none of the returns at the preceding censuses were, I am convinced, based on actual analysis of the pay-rolls. They were in nearly all cases mere estimates made more or less offhand by the manufacturer or his bookkeepers, and there is every reason to believe that these estimates were often wide of the mark.

The revised schedule will call for the total number of employees on the first pay-roll of each month, regardless of age or sex. In order to throw some light on the relative numbers of men, women and children employed, a single pay-roll, only, will be analyzed.

Census inquiries of such a character as to make correct answers impossible, in the language of Mr. Durand, "tend to injure the accuracy of the replies to all the other interrogatories in the schedule." Both census agents and manufacturers "were practically forced in many cases to make estimates in replying to" some of the interrogatories of the past,

> and this practice tempted them to regard estimates as sufficient also in replying to other interrogatories in the schedule. The intellectual integrity of the special agents was undermined by attempting to require of them work which they knew could not be done accurately within the time which they were allowed.

The statements in the immediately foregoing quotation show a discernment which, if applied to future censuses as a whole, will unquestionably raise them to a much higher plane than those of the past. Of course progress is to be expected in each succeeding census, especially now that we have the long-desired permanent census bureau.

Perhaps it is too much to expect, but certainly we may hope that the time will yet come when the census inquiries as a whole will be so reasonable, and at the same time so well standardized, that the results of one census may be compared with those of another, without so many qualifications and allowances as have been necessary in the past. It is of course unavoidable that changes in substance and method of inquiry will be necessary from time to time, and that these in turn will make necessary certain allowances in comparing the results of one census with those of another. But in the past, these necessary allowances have sometimes been so extensive as to make the comparisons themselves of little value. Those who do not grasp the force of statements in the last two or three sentences may refer, if they wish, to almost any of the census reports dealing with a line of inquiry which had been gone into in previous years. The introduction in almost every case proceeds first of all to tell how the results of a given census are not comparable with those of the preceding one, and to state the reasons why. This unfortunate state of affairs is largely due, we believe, to the very fact of which Director Durand is now taking notice: namely, over-ambitious and over-elaborate schedules, impossible of being filled in accurately within the limits of available knowledge and time on the part of both the census agents and those who are being interrogated.

In our issue of Oct. 21, 1909, we illustrated the new speed-reducing gear for marine steam turbines invented by Rear-Admiral Melville and his partner. We gave space to this device because it was attracting wide attention in the newspapers and is an ingenious attempt at working out what is unquestionably a very important problem in marine-engineering development. While we made no comment upon the device at the time of its publication, it seems proper that we should point out some of the reasons which make it extremely doubtful whether it can be successfully applied to the practical work of ship propulsion.

As our readers who have examined the device will recall, it consists of a gear and pinion with spiral teeth meshing with each other, the pinion being on the turbine shaft, of course, and the gear on the propeller shaft. In the experimental machine which the inventors have constructed, a gear tooth of 1¼ ins. pitch is used and a load is assumed upon it of about 450 lbs. per lin. in. This is claimed, doubtless with truth, to be well within the limits of safe working pressure for gears of high-quality alloy steel. But the question which will give pause to the ship owner or naval engineer who may seriously consider the introduction of such a device on board his ship, will be the question of the effect of shocks upon these gear teeth. It is perfectly well known that the forces to be met with by the propelling machinery of a ship in a rough sea defy all attempt at calculation. When the ship pitches heavily, the screw is alternately raised wholly or partially out of the water and then buried deeply in it. The force of the waves which strike the screw in a heavy sea can be appreciated to some extent by consideration of the damage done to other parts of the vessel by occasional huge breakers. It is well known that the wrenching which the propeller gets in heavy seas often causes fracture of the huge screw shafts themselves.

To introduce, now, such a delicate thing as toothed gearing, no matter of what form or of what material, between the engine shaft and the propeller shaft, is to introduce a weak link into a chain. It is manifest that the strength of these teeth cannot possibly be anything like as great as that of the shafts which they connect. As to how much pounding a gear of this sort might stand before the teeth would strip, no engineer could possibly prophesy—nothing but actual trial could determine; but in any event the weakness of the connection is so evident, and the serious danger to a vessel which should be deprived of her motive power through such a failure is so well known, that no vessel of much value is likely to be hazarded in a trial of the device.

Boston is to be the first large city in the country to try a radical change in the administration of its municipal affairs, in line with the agitation of the last few years for concentrating responsibility and reducing the number of elected officers. Under the new plan of government adopted by popular vote on Nov. 2, the city government hereafter will be entrusted to a mayor and nine councilmen. The councilmen will be elected at large, and, after the readjustment required by the change, will serve for terms of three years. All other important offices will be filled by appointment, thus reducing the annual municipal ticket to three councilmen, together with a mayor once in four years, and possibly once in two years*. The mayor will have sole power of appointment and dismissal (for cause) of all heads of departments.

It is significant and highly encouraging to note that the plan adopted is substantially the one

*Members of the school committee are not here taken into account. They will continue to be elected by popular vote.

recommended by an investigating committee known as the Finance Commission, although the State Legislature in its wisdom compelled the voters to choose between (1) this plan and (2) an alternative which provided for 36 councilmen (9 of them elected at large and the rest by wards), together with a two-year term for the mayor, all candidates to be chosen by the old primary and convention plan of nomination, instead of by the mere filing of petitions as recommended by the Finance Commission.

A number of other interesting features of the new plan of government were stated in Engineering News of July 15, 1909, in which an outline was given of the legislative act putting in force the main recommendations of the Finance Commission and providing for a vote on the alternative plan just outlined. The report of the investigating committee, or Finance Commission, with its many startling findings of maladministration, was abstracted at some length in our issue of March 25, 1909; while in the same issue appeared a long editorial discussion of the charter amendments proposed for both Boston and New York, and also of the new charter of Berkeley, Cal.

Although the new city council of Boston will be composed of but nine members, as compared with the former bicameral body of 75 in a lower and 13 in an upper house, yet it is quite different in many of its essential features from the so-called commission plan of government. Under the commission plan, as in use at Galveston, Des Moines and many other relatively small places, and as recently voted for at Tacoma, Wash., the city administration consists of a body of five men, including the mayor. This body has both legislative and administrative functions. At Boston, under the scheme which will go into effect in February, 1910, the powers and duties of the mayor and of the council, respectively, will be differentiated rather more sharply, on the whole, than has ever been the case heretofore in an American city. And with this differentiation there will be a sharp separation of legislative and administrative powers.

A unique feature of the new Boston plan of government, the results under which will be watched with interest, is a permanent finance commission having somewhat the same general powers of investigation of all phases of city affairs as was given to the temporary commission which was so largely responsible for the changes in government which are taking place at Boston. The new finance commission, which has already been in existence for some months following the legislation of 1909, is extra-municipal in origin: that is to say, it is appointed by the governor. This might seem to be a serious infraction of municipal home rule, but it can hardly be so considered in view of the fact that the powers of the commission are restricted to those of investigation and criticism.

Engineers will be particularly interested in the fact that appointments made by the mayor need not be restricted to citizens of Boston, and that their fitness for their special work must be certified to by both the mayor and the city civil service commission. In urging this feature of the charter amendments, the old Finance Commission stated that graduates of the Massachusetts Institute of Technology were recommended by their professors not to enter the city service on account of uncertainty of tenure of office and other unsatisfactory conditions connected with old-time party government.

It is perhaps worth noting that of a registered vote of 108,493, a total of 74,211 were cast on the charter amendments, or nearly 70% of the total registration. The plan adopted was carried by a majority of 3,869 votes, notwithstanding the fact that the political leaders of both parties worked hard for the larger as opposed to the smaller council, with election largely by wards instead of wholly at large, and with nominations by party primaries in general convention instead of by petition. It may be added that under the new plan 5,000 petitioners may secure the placing on an election ticket of a candidate for any office; also that toward the end of the first two years of the term of any mayor a vote will be taken on whether or not there shall be an election for a mayor. This is a modified form of the recall plan which has been adopted in a number of western cities and which has recently resulted in the deposition of the Mayor of Los Angeles after serious charges.

Now that the voters of Boston have shown so much interest in the form of their municipal government, as evidenced by the heavy vote cast, and have declared so unequivocally for sweeping reforms, it is to be hoped that by one means or another the people of New York will either be given the new charter framed with so much care by the Charter Commission during the past year, or else be allowed to express their disapproval of the plan. While the proposed charter reform for New York City does not go so far in the way of administrative changes as the plan just adopted for Boston, nevertheless it is a long step in advance of present charter regulations. An outline of the proposed New York charter was printed and discussed in our issue of March 25, 1909.

A noteworthy item among the proceedings of the International Association for Testing Materials at its Copenhagen congress last month was the passage of a resolution soliciting financial assistance from governments and other public bodies. The Association requests us to give it "proper publicity." The resolution reads as follows, in the quaint English of the official translator:

> In consideration of the great importance of the work of the International Association for Testing Materials for the public security and in consideration of the necessity to make their work as widely known as possible and to place the finances of the Association upon a more satisfactory basis, the Congress decides to authorize the Council to call the attention of governments, public bodies and scientific and industrial undertakings to the work of the International Association and to induce them to manifest their interest therein by giving financial support.

It is not easy to see any good reason why this voluntary and unofficial association should be supported by Government funds. The field of work of the Association is no more in the special interest of the public than is the work of many other scientific and semi-scientific organizations, which manage to get along on their own resources. The expenses of the Association are small. The class from which it draws its membership is not so poor in this world's goods as to be incapable of financing its own societies. In each of the chief civilized countries there is a flourishing national society of material-testing, which proves that the general subject is attractive and important. It would seem then that an international association, if there is a real demand for its existence, should be able to pay its own expenses. But if it cannot pay its way, if it cannot secure enough members, or fix its dues sufficiently high, to cover its small necessary expenditures, it would look as if its field of usefulness could not be very great, and if that is the case one can hardly make a strong argument for Government assistance.

An interesting illustration of the extent to which Engineering News is read by engineers in all parts of the world is furnished by two letters which have recently appeared in our correspondence columns, both dealing with a minor detail of railway track construction and both referring to information published in Engineering News regarding this subject. In our issue of July 15 we published a letter from the Chief Engineer of the Queensland Government Railway in Australia describing his practice in regard to the use of guard rails on sharp curves, and mentioning the details as to American practice in this matter which had been given in the tables of track construction of American railways in our issue of June 4, 1908. This week we publish a letter on the same subject from the Chief Engineer of the Natal Government Railways (South Africa). It is pleasing to note that the information as to American practice, which was gathered and compiled with considerable care and trouble, has been found of practical value to engineers not only in this country but also in far distant parts of Australia and Africa.

The Sanitary Condition of the Merrimack River and Observations on Stream Pollution in General.

A rational view of the use of the Merrimack River for the disposal of the sewage of the populous cities and towns on its banks is taken by the Massachusetts State Board of Health in its report to the legislature, printed in part elsewhere in this issue. The gist of its conclusions is that, with the correction of obviously excessive and unreasonable pollution at a few points on the river or its tributaries the stream may continue to be used for the disposal by dilution of the sewage of many communities, large and small. For the present, the river is not in a condition to be injurious to the public health, and by proper regulation it may be kept for many years, perhaps generations, free from danger.

The correction of various existing cases of pollution, many of which are relatively minor, is suggested, particularly those due to wool-scouring wastes, and the legislature is advised that it would be well to give the board additional powers of sanitary control of the river.

The report shows the value of the water-pollution studies the board has made during the past 21 years. No other state in the Union has made such long-continued detailed sanitary studies of individual streams as has Massachusetts, but in a few instances good beginnings to the same end have been made.

Perhaps the most important lesson to be drawn from this Merrimack report lies in the practical common sense exhibited in its conclusions. Here we have the pioneer and long-time American leader in stream sanitation, after reviewing water-pollution data unsurpassed anywhere in the world, and that at the instance of a legislative resolution which would warrant the recommendation of drastic measures, calmly reporting mild measures of reform, looking chiefly to the future. What a contrast to one of our western state boards of health which, a few years ago, issued a blanket order for the construction of septic tanks by all the municipalities of the state, having or building sewerage systems, quite regardless of local conditions. It is only fair to add that the board in question subsequently took a saner attitude.

Desirable as it would be in many respects to prohibit the discharge of untreated sewage into any and all streams it will be many years hence before that will become practicable. In fact, it is doubtful whether it ever will be practicable in the case of many of our larger streams, except for such minor reduction of polluting matters as may be effected by screening, or screening and a short period of sedimentation.

As we have said repeatedly, all practicable means of sewage disposal depend on either land or water, and ultimately the liquid portion of sewage must reach water. Disposal into water, or by simple dilution, must be the chief reliance of the urban population of the world for many, many years to come. Under reasonable limiting conditions, which for the present are oftentimes so generous as to be almost or quite negligible, sewage disposal into water is quite as allowable as disposal on land. The actual limiting conditions in any given case, and particularly for a stream of any size, can rarely be determined off hand. Preferably they should be established after the study of such data as those available to and reviewed by the Massachusetts State Board of Health in the case of the Merrimack. But outside of Massachusetts such extensive data are not available. Fortunately, they are not absolutely necessary for sane and safe conclusions, however desirable they may be. Unfortunately, most of our states have all they can possibly do for years hence to clean up streams the pollution of which is already so serious as to require for their selection no more scientific observations than those which can be made by the eye and nose. Wholesale campaigns against water pollution would be the height of folly in such cases.

What is wanted is the exercise of careful judgment in dealing with one stream or city after another, beginning first with positive dangers to health and proceeding gradually down the scale

to and through probable and then possible dangers to health and on to grave and then to lesser offenses against the senses.

There is need enough for just such a campaign in every state, but as yet it has been entered upon by only a few. As a final word of caution to those whose newly awakened zeal is not yet tempered with the discretion that comes with full knowledge and experience, we would again call attention to the fact that water pollution is only one of the many sanitary evils demanding the untiring efforts of reformers and the golden millions of our public treasuries. There is a sharp limit to the burdens of taxation and of bonded debt which the people will bear, and so if the greatest good to the greatest number is to be the motto in sanitation, as in other lines of endeavor, wisdom must be exercised in apportioning available funds between the multifarious worthy objects of public expense.

The Available Water Supply of the Panama Canal.

In the October "Proceedings" of the American Society of Civil Engineers, Mr. Julio F. Sorzano presents a paper in which he discusses the water-supply for the Panama Canal and reaches the conclusion that the water stored in Gatun Lake will not be sufficient to provide for lockage throughout the dry season.

To analyze in detail Mr. Sorzano's assumptions and conclusions would require more space than it seems worth while to give here. Doubtless, when the paper is presented before the Society at the meeting on Nov. 17, there will be some authoritative statements made in reply to the arguments of the paper.

We may point out at this time, however, that Mr. Sorzano reaches his conclusions by assuming very large losses from the future Lake Gatun. For example, he assumes that there will be a percolation from the bottom of the lake into the underlying strata averaging nearly half an inch a day. He bases this assumption on what he appropriately terms an "empiric rule"; and he endeavors to support the assumption by quoting figures of seepage from a number of *canals* used for irrigation and navigation.

It would seem well-nigh self-evident to an engineer that to attempt to apply, even remotely, the figures for seepage from a canal, to percolation through the bottom of a storage reservoir into the subsurface rock, is to compare two things that are wholly unlike. If the figures for canal seepage really applied to reservoirs, a good share of all the storage reservoirs now in use for irrigation and for municipal water-supply would lose a very large part of their usefulness.

The fact is that there is no reason to expect any greater seepage loss from Gatun Lake than from the lakes in the Croton watershed supplying New York City, or from hundreds of other well-known storage reservoirs. If anything, the conditions in the Chagres Valley are less favorable to percolation than they are in most sections of the United States. The rocks in the Canal Zone which have been penetrated by the deep excavations of the past five years have not proved as water-bearing, on the whole, as the average rock met with in excavation in the United States.

Mr. Sorzano assumes, also, 20 lockages per day in each direction, which would provide for annual traffic through the canal of something like 20,000,000 tons. It has been fully established by the experts who have investigated the probable canal traffic, that nothing approaching such a vessel movement through the canal can reasonably be expected for a number of years after the canal is opened, possibly not for half a century. It is well understood by those who have given thorough study to the subject, that for a considerable time after the canal is opened, the volume of traffic through the canal will probably be so small as to cause great public disappointment and criticism. However, it is of course true that the traffic which Mr. Sorzano assumes must be provided for—if and when it is offered, be it sooner or later. Let us assume also that Mr. Sorzano's extravagant assumptions as to seepage from the lake should actually be realized, and that all his other assumptions as to losses of water from the lake should prove correct. It does not at all follow, as he assumes, "that the insufficiency of water limits for all time the capacity of the lock canal." What would be done in that event, and what has indeed been contemplated from the beginning by the numerous distinguished engineers who have investigated the water-supply of the canal, is to build a great storage reservoir on the Upper Chagres, where a favorable site exists at Alhajuela. The dam location at Alhajuela was thoroughly explored by the International Comité Technique, and plans were made for providing a reservoir there with an area of about 12 square miles. This area could doubtless be readily increased, and there are besides other available sites for storage reservoirs in the upper reaches of the rivers flowing into Lake Gatun.

Mr. Sorzano in his paper refers, indeed, to the projects for such reservoirs, and expressly states that he *excludes* such reservoirs from consideration in his discussion. But why should he ignore these reservoirs? The ultimate possible need of these reservoirs has been recognized by the canal engineers for twenty years past. In fact, if Mr. Sorzano had carefully studied some of the available literature on the canal water-supply, such as the paper of Gen. Henry L. Abbot, published as Appendix E with the report of the Board of Consulting Engineers for the Panama Canal of 1906, it is doubtful whether he would have written his paper at all.

Some may question, however, whether the dam and reservoir at Alhajuela ought not to be provided for in the present plans. The answer to this question is that, according to the best data available, the water-supply in Lake Gatun will be ample for all the traffic that will seek the canal for a long time after it is opened. Whenever it becomes evident that an increased water storage is going to be needed to tide over the dry season, the dam at Alhajuela can be built, and at far less cost than if it were undertaken now.

LETTERS TO THE EDITOR.

Specifications for the Analysis of Road Binders. —An Answer to Mr. H. Tipper.

Sir: In Engineering News of Oct. 7 Mr. Tipper, Publicity Engineer of the Texas Co. (a company dealing in asphaltic oils, etc.), had an article in regard to asphaltic specifications in which he undertakes to criticize with considerable severity certain specifications emanating from the Massachusetts Highway Commission; and in his article has much to say in regard to "ignorant chemists," etc., who promulgate such specifications. As I and my assistants are the chemists to whom Mr. Tipper refers, we feel, of course, properly humbled by the chemical criticisms of the publicity engineer; but perhaps some discussion of his article is allowable on our part.

I have had some communication with the Texas Co. and its chemist, and happen to know something of the attitude of that company towards the Massachusetts specifications and work during 1909.

In the first place, allow me to say that the Massachusetts Highway Commission's specifications are not considered perfect by us, and that when first outlined by me at the meeting of the American Society of Civil Engineers, in New York, at which this subject was discussed, I frankly stated they were simply specifications gotten out for 1909, that we hoped to improve them, but thought that with them we should be able to obtain such materials as we believed at that time had been, and would be of the greatest value in the Massachusetts work. This statement has been fairly well justified by experience with these specifications during 1909. It is well, also, to call the attention of the reader at this point to the fact that at the end of Mr. Tipper's article we find a set of specifications made by the chemist of the Texas Co. which Mr. Tipper evidently believes is the right thing. It is of course apparent, however, from these specifications and the general tenor of Mr. Tipper's article, and also from interviews and correspondence on my part and the part of the commission with the chemist of the Texas Co., that these specifications are made to fit the favorite product of that company. In other words, the Massachusetts specifications are put together to enable the Highway Commission to buy the materials it desires, while the Texas Co.'s specifications are put together to enable that company to sell the material it desires to sell. It may be a good material, but the facts are plain as regard these specifications and are as stated.

Turning to Mr. Tipper's criticisms, he states that it seems absurd to specify in one paragraph that the material "shall not contain more than 0.5% impurity" and in the latter paragraph "that it shall not contain more than 1% of matter insoluble in carbon bisulphid." It is sufficient answer to say that this was intended to prevent more than 0.5% of dirt or mineral matter and more than 0.5% of free carbon.

The statement that the asphalt oil shall contain no bodies not naturally present in asphalt oil, is perhaps not as ridiculous as Mr. Tipper believes, although perhaps not absolutely necessary. It certainly did not apply to bodies present in the crude oil, but would bar out undesirable accidental impurities such as water, etc.

As Mr. Tipper says, the second paragraph in these specifications calls for a specific gravity of not less than 0.97, but he also adds that no evidence has been adduced as to just what influence the specific gravity has on a binder and no such specification should be included until such time as evidence of this kind is definitely known. In answer I can say that the reason this specific gravity was selected as a minimum, was because it was found by *actual experience* here in Massachusetts during 1908, and abundantly confirmed in 1909, that asphalt oils of a lower gravity, other things being equal, would not produce the results that the Highway Commission desired.

The reason for setting a maximum limit of 10%, insoluble in petroleum ether, was that the oils actually found most satisfactory by experience in Massachusetts were below this limit. The percentage of the binder insoluble in petroleum ether has a decided effect on the body or viscosity of the oil, which is not shown by the percentage insoluble in carbon bisulphid.

Frankly, we can say, that in the light of experience during 1909, the fourth paragraph of the specifications relating to the amount and temperature of distillate will undoubtedly be modified. Mr. Tipper's criticism of the viscosity specification is hardly well-founded. He does not believe in a minimum viscosity test, but such a test is necessary in order to shut out oils with insufficient body.

No attention has been paid in our specifications in regard to the percentage of asphalt as ordinarily determined, it being proved by us that the desired body or consistency can be obtained from the specific gravity and viscosity determinations. It has never been clear to the workers in these laboratories how a fairly liquid oil with a specific gravity of 0.97 can contain 90% of asphalt, as one would infer from Mr. Tipper's article and from other articles, when a solid, hard asphalt can have only 100%. In Mr. Tipper's paragraph criticising these tests, he apparently loses sight of the fact that the viscosity of the material at the ordinary temperature of the road is of more importance than its viscosity at a working temperature, since the former determination to a considerable extent shows the binding power of the material in the finished road, while the latter is simply an incident in the building of the road. In fact, Mr. Tipper desires a material specified which is easy of application regardless of its value as a permanent binder; or in other words, he is looking out for the selling end of the business rather than the permanency of the road.

After a year's work with our viscosimeter we can say that it is a time-saver compared with others, and better suited for the work at hand than any of the well-known makes on the market.

Mr. Tipper goes to considerable length to criticize the 21 hours evaporation test and states:

> An earlier requirement in these specifications says that the material shall not distill at less than 250°C. Hazy memories of technical training seem to indicate that distillation is a matter of evaporation and of recondensation. Therefore if there is no distillation below 250°C. why is it necessary to call for a test at 100°C. and specify not more than 5 per cent. loss in this test, if the material does not lose any at all below 250°C.?"

The reason for the evaporation test is that asphalt oils which lose any considerable weight under the conditions of the test have been found by actual experience to be less satisfactory than those that lose little. Of course the conditions of the test are empirical, as any such test must be. The hazy memories of Mr. Tipper in regard to technical training may be refreshed by the plain statement of the fact that liquid bodies will evaporate readily at a temperature far below distilling point.

I should also like to call attention to the fact that in his discussion Mr. Tipper distinctly assumes that asphalt binders after application to the road, harden entirely on account of concentration by evaporation. Surely he cannot believe the road gets hot enough to distill the oils from the true binder, and yet he seems to believe this. (See his statement about puzzles, etc.) That much of this hardening is probably an oxidation, is indicated by experience on the road and by the fact that some oils gain in weight during this 21 hours evaporation test. The briquette test mentioned in the specifications has been of value a few

times during the season by shutting out materials that were evidently undesirable and yet passed or nearly passed all the other tests in the specifications.

After all Mr. Tipper's discussion, we come to the end of his article and find the real object of his plaint, where he says:

It will naturally be asked after such criticism of the present condition of the affairs, have you any remedy to suggest?

And then he cheerfully presents the specifications under which the Texas Co. desires to sell its product, and states just what in the opinion of the Texas Co. or its chemist, or its publicity engineer, the standard of a binding material should be. His series of tests could be easily criticised but that is not the object of this letter, for I do not desire to be drawn into an acrimonious discussion.

H. W. Clark.

Chemist, Mass. State Board of Health and Mass. Highway Commission. Boston, Mass., Oct. 25, 1909.

A Common-Sense View of Petrolithic Road Construction.

Sir: Referring to the closing sentence of Mr. T. A. Hulbert's letter about petrolithic road construction, on page 440 of your issue of Oct. 21, 1909, to the effect that the critics of this construction were arraying themselves against sound theory and good practice: my statement in your issue of Sept. 23, 1909, was called forth by the assertion of an advocate of petrolithic that,

Whether the material is soil, sand, gravel, worn-out macadam or other granular and stable material, makes little difference as to the final good character of the completed pavement.

This declaration lays the foundation for neither sound theory nor good practice, but rather for the trade catalog testimonial and the extravagant claims of the commercial agent. The latter cannot change the character and action of the materials of construction.

Quite different from such advocacy are the specifications and qualifications for petrolithic which have responded to my criticism. If the latter continue, I will soon be in accord therewith.

For city pavement in residence districts, petrolithic is undergoing an evolution and an advance toward macadam construction with a bituminous binder. When it attains its logical development and highest efficiency, it will be an improved macadam pavement with a dustless binder, giving the requisite strength to resist motor car travel. Then, the name "Petrolithic" will have lost special significance, except in as far as the petrolithic process shall still be used in the preparation of the earth foundation on which macadam construction usually rests.

The original petrolithic earth and oil road made without the addition of the broken stone which is now being added in increasing quantities was not, of itself, a pavement in the proper sense; but it was an excellent earth foundation on which to build any class of high-grade pavement.

It is of particular significance that all of the advocates of petrolithic admit that the addition of broken stone or gravel to the earth makes a better roadway, and, unless the natural surface is already composed of good gravel and sand, broken stone is added. The next step in advance will be the entire separation of the earth and stone, placing the latter on top where it belongs.

Yours truly,

J. L. Campbell.

702 Southwestern Building, El Paso, Tex.

Continuity in Reinforced-Concrete Beams.

Sir: Referring to the above article of Mr. Spaulding in your issue of Sept. 18 and the several replies to it in the Oct. 28 issue, I beg leave to again bring up this matter because a very important point seems to have been overlooked.

The important fact has already been hinted at, that it is one of the great advantages of reinforced-concrete structures that the monolithic nature makes a design to be the more economical and perfect the more it approaches the ideal theoretical condition. That means that in a continuous beam the moment of resistance at the support should be twice as large for dead-load and about 40% larger for live-load than the moment in the center. Neither the original article, however, nor the replies mention how easily this distribution of strength is to be attained without excessive reinforcement over supports by providing short brackets at the supporting columns, as is being done right along abroad.

The arrangement of brackets seems to be dreaded by contractors on account of additional expense in centering. It appears, however, to be merely a question of standardizing this bracket centering, in a similar way, as is being done for straight beam boxes, in order to reduce the additional cost to a minimum. Reinforcement on top needs only to be one-half the length of the bottom reinforcement and at that the increased depth on the bracket increases the efficiency of the unit of top steel area. Thus the bracket effects a considerable saving in material and at the same time makes it possible to reduce the depth of the beam in the center.

O. Gottschalk.

Detroit, Mich., Nov. 5, 1909.

Tie-Plates and Braces for Guard Rails on Sharp Curves; Natal Government Railways.

Sir: I have read with interest an article which appeared in your issue of June 4, 1908, as well as correspondence on the subject of guard rails on curves which you have published in more recent numbers, and as your paper is so largely read not only in the United States, but in many of the English colonies as well, I venture to think you may be interested to see the device which has been evolved to minimize the heavy wear and tear which occurs on the mountain sections of the Natal Government Railways.

Originally we used the most obvious expedient of connecting the two rails together by bolts and distance blocks placed at short intervals, but with the increase in weight of engines and cars this was found to be quite inadequate, through the breaking of the bolts. Experiments have led to the evolution of a form of wrought steel tie-plate and rail brace, illustrated herewith.

I am aware that in America you have the advantage of your facilities for making malleable castings in designing somewhat similar chairs and braces, but we have availed ourselves of the modern process of stamping wrought steel plates into forms which we have found to give most satisfactory results. These have enabled us to effect very great economies in the maintenance of sections of our road, on which curves of sharp radius are combined with steep gradients. In the worst instances, curves of 300 ft. radius are combined with uncompensated gradients of 1 in 30.

On such sections, we have in use tender engines weighing 106 tons with cars of a maximum gross weight of 50 tons on a track of 3 ft. 6 ins. gage, so you will gather that our conditions are probably as destructive to the track as exist anywhere in the world.

This device has enabled us to retain rails in the track for a period of three years instead of but three months, as used to be the case before the device was adopted.

The interest with which I have read the information given in your paper of the practice elsewhere in the matter of curve guard rails is my excuse for sending you these particulars of what is being done here.

Yours faithfully, John W. Shores,
Engineer-in-Chief, Natal Government Railways.
Pietermaritzburg, Natal (South Africa), Sept. 7, 1909.

[The question of guard rails on curves is of special importance on railways where curves of sharp radius are frequent, and the use of these guard rails is not only in the interest of safety but may effect an important economy in track maintenance, as is shown by the above letter. In our issue of July 15 we published a letter from Mr. W. Pagan, Chief Engineer of the Queensland Government Railways (Australia), describing the arrangement used on those railways.

In this country, curve guard rails are sometimes secured only by spikes, but this does not ensure the maintenance of the proper distance between the guard and running rails, and the better practice is to connect the rails by bolts with spacing blocks. On the Natal Government Railways, however, it appears from the above letter, that bolts have not proved satisfactory, and the method adopted is to use a heavy pressed-steel tie-plate or chair having lugs to fit the adjacent flanges of the two rails. The guard rail is supported by a rail-brace which fits against a lug on the tie-plate, while the running rail is secured by a steel key driven between the outer

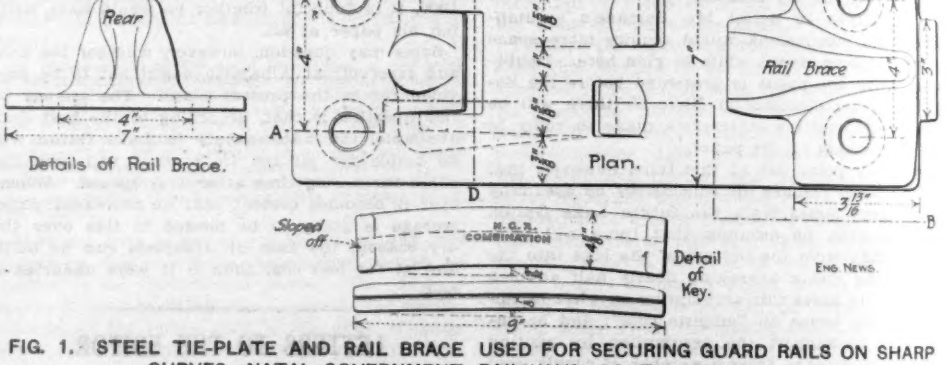


FIG. 1. STEEL TIE-PLATE AND RAIL BRACE USED FOR SECURING GUARD RAILS ON SHARP CURVES; NATAL GOVERNMENT RAILWAYS (SOUTH AFRICA).

FIG. 2. STEEL TIE-PLATE AND RAIL BRACE FOR USE WITH GUARD RAILS ON CURVES.

flange and a lug on the tie-plate. As the tie-plate and rail-brace are secured to the tie by screw spikes, the track should be very secure, while the arrangement of the lugs is such as to ensure the maintenance of the two rails in their proper position and proper distance from each other.—Ed.]

The Spacing of Rods in a Reinforced-Concrete Beam.

Sir: There are some phases in the analysis of a reinforced-concrete beam that are in a very hazy and unsatisfactory state in literature on the subject. One of these concerns the spacing of rods in the bottom of a beam. How far apart should they be to satisfy the requirements of consistent construction?

Professors Maurer and Turneaure, in their book "Principles of Reinforced-Concrete Construction," p. 174, 1st ed. (p. 226, 2d ed.), say:

If the bars are circular, it may be assumed that one-half of the stress in them is given over to the concrete below, hence the strength of the concrete on a longitudinal section through the center plane of the bars must equal one-half of the stress in the bars. If the shearing stress be taken as equal only to the bond stress then the clear space between bars must be one-half of the circumference of a bar, or 1.57 diameters. . . . In the case of square bars, on the same basis, the clear spacing would need to be 1½ diameters if the bars are placed with sides vertical or one diameter if placed with sides diagonal.

I can see at least a partial reasoning in the process of deriving the spacing of the round rods, if the fact be ignored that the same concrete is counted twice in shear above the horizontal line through the center of the rods; that is, the excess of periphery of the bar above the line over the diameter of a bar must take shear coming from the space between the bars and from the upper half of the bar. I fail to see any reason whatever for the space 1.5 d in the case of square rods with sides vertical or the space d when the square rods are placed diagonally.

If shear and bond are equal, the conclusion is inevitable that the space immediately above the bars must be equal to the periphery of the bars, as all of the tension in the bars must get to the upper part of the beam in order to be counteracted by compression in the latter. This would be 3.14 d spacing for round bars and 4 d for square bars, altogether independent of the angle of the square bars.

It would be just as rational to count the rivets in the flange angles of a plate girder connecting to the cover plate as taking horizontal shear into the web as it is to space bars in a reinforced-concrete beam on the reasoning quoted above.

The foregoing may seem like a point of theoretic importance only, but such is not the case. It is not uncommon to see bars spaced close together in the bottom of a beam; sometimes two banks of bars are used and the width of the beam is only a fraction of the periphery of the bars. Designers seem to think that deformed bars are especially privileged in this respect because of some magic property of the deformed bar. If a deformed bar is capable of greater grip in the concrete, it simply means greater shear in the beam and more width needed in the same to take that shear. This is where the supposed advantage of a deformed bar goes a-glimmering. If there is enough concrete in the beam to grip a bar and carry the shear, it will grip a plain bar with all of the strength needed. It will further need no assistance from the slab in the compression flange, and a T-beam, except with bars bent up and anchored at ends, has no place in calculations.

In many beams the bars do not run horizontally to the end but are bent up near the support. In such cases it might be thought that shear would be less across the beam and bars could be laid closer together. This can only be the case where the bent up bars have end anchorage or run into adjacent (end to end) beams. When the bars bend up and stop at the ends of beam, it is simply a poor design. The other bars or the concrete are over-stressed, and exactly the same horizontal shear must be taken by the beam as though the bars were all straight.

Yours very truly,
Edward Godfrey.

Monongahela Bank Bldg., Pittsburg, Pa., Oct. 22, 1909.

Gaging of 52-in. Riveted Pipe at Los Angeles.

Sir: In your issue of Sept. 23, 1909, J. B. Lippincott, M. Am. Soc. C. E., gives some experiments on pipes, which furnish valuable information owing to the care with which the observations were made.

However, in the case of the 52-in. riveted steel pipe, it seems to me that some of the data necessary to apply the Chezy formula for the coefficient C were omitted. Hence the following questions:

1. What kind of a conduit led to the upper end of the siphon?

2. What was the cross-section of the wetted perimeter of this conduit and the mean velocity in it when the observations were made on the siphon?

The first question is important because, if the water reached the siphon through a closed conduit, it would be necessary to know that there was no pressure created at the siphon entrance. The second question is still more important, because unless the velocity in the conduit above the siphon were equal to that in the siphon, a correction of the observed slope would be necessary. To change the velocity of water from a lower to a higher one involves the expenditure of head, which must be deducted from the total observed head on the siphon. The reverse condition calls for a correction in the opposite direction. This is the "acceleration head" problem, which must not be confounded with the "entry head" as commonly understood and involving but a slight loss due to contraction at the pipe intake.

Respectfully,
F. C. Finkle.

Los Angeles, Cal., Sept. 28, 1909.

[In reply, Mr. Lippincott refers to an earlier letter to us, written Sept. 3, in answer to our inquiries for exact description of methods. It contained the following statement in reference to the 52-in. riveted steel pipe:

In the 52-in. steel pipe the difference in level between the surface level of the water entering the pipe, after it had taken its drop down curve to its static level, and the surface of the water at the exit, after it had reached its level in the conduit, was obtained. In this way all entry heads were eliminated. This difference in level was found by ordinary levels carefully run and checked from the original benches from which the conduit was built. The possible error in this is very small.

The measurements of the discharge were made from two permanent gaging stations, by current meters which have been in use since 1903, and have been carefully calibrated. One station is some distance above the pipe and the other directly below it. The discharge was also checked by volumetric measurement in a reservoir below.

—Ed.]

A Suggested Numbering for a Stadia Rod.

Sir: Since reading the description of the Fish stadia rod in the Oct. 7 issue of the News the writer has worked out the following arrangement for the markings on a stadia rod. Start with zero at 3 ft. from the bottom of the rod and run up the rod with the figures 1, 2, 3 and so on consecutively to zero again or ten feet; using Professor Fish's one-half foot figures this would make the rod 13½ ft. long. Start at zero again and run down the rod, mark the first, second and third or bottom foot F, S and T, respectively. Paint these three letters, the figure 2 and the upper zero red; all other marks black.

The majority of stadia shots are under 600 ft. Therefore, when the rod is marked in this way and the bottom crosshair is set on zero, the middle crosshair will be close to the 2-ft. mark or 5 ft. above the ground in the majority of cases. The figure 2 is in red to help the transitman set on his H. I. readily. The other red marks are the ones which are used when the shots are over 1,000 ft. long. When reading a distance of more than 1,000 ft., set the top crosshair on the upper zero and take the rod-reading of the bottom crosshair, counting the lower zero as 10 and F, S and T as eleven, twelve and thirteen, respectively.

The advantage of this rod is that the rod-reading at the second crosshair gives the uncorrected distance directly and eliminates the possibility of forgetting to subtract the rod-reading of the first crosshair. It is not practical to set the bottom crosshair on the zero of the rods as they are marked at present, because it is generally hidden behind several inches of grass or leaf mold; besides, this would generally carry the middle crosshair some distance from the 5-ft. mark.

Robert S. Beard.

Warwick, N. Y., Oct. 24, 1909.

The Earliest Use of the Shield for Soft Ground Tunneling.

Sir: Your editorial in your issue of Oct. 21, 1909, stated that the Beach tunnel under Broadway, the shield for which was patented by Mr. Alfred E. Beach as of date June 8, 1869, showed that "The possibilities of sub-surface circular tunneling beneath city streets were appreciated on this side of the Atlantic nearly 20 years before English engineers developed the shield-driven tube tunnel system beneath London streets and the waters of the Thames."

As a matter of historical accuracy, might I inquire if you have not overlooked the construction in 1868 by the late James H. Greathead of the Tower Subway, crossing the River Thames in London, England? This tunnel is 7 ft. 1⅜ ins. external diameter and is about 2,000 ft. in length. Access to it is gained by means of shafts provided with spiral stairways placed under the streets some distance back from the water fronts on each shore. The tunnel was driven by means of a shield propelled with screw jacks bearing on the last ring of metal lining, when a speed of about 9 ft. per day was attained in "London clay." You will observe that this tunnel is therefore both under the London streets and the waters of the Thames.

This tunnel provided a much needed crossing for pedestrians and was greatly used up to the time of the opening of the Tower Bridge by the working classes around Billingsgate and Bermondsey, who paid half-penny toll charge. When the Tower Bridge was completed, the owners of this subway were recompensed by the city, and in investigating this matter of compensation for the owners (as well as I can recollect this was in 1896) it became my duty, on behalf of Mr. Greathead, to have a piece of the metal lining of this tunnel cut out as an exhibit of its condition. This metal, which had had a bath of coal tar, was in an absolutely perfect state of preservation. The tunnel has since been converted, I believe, into a conduit for either gas or water pipes, or both.

Yours very truly, James Forgie.

Penna. Station, New York City, Nov. 6, 1909.

[We give space with pleasure to our correspondent's correction. In penning the sentence criticised, we had in mind the active work in constructing tube tunnels for passenger transit in London which began in the late 80's, and in which Mr. Greathead took a leading part, and we overlooked the much earlier Thames subway, which Mr. Forgie describes. In this connection the following paragraph from Engineering News of Jan. 30, 1902, is of interest:

At the American Institute Fair held in New York City in 1867, Mr. Alfred Beach had on exhibition a circular wooden tube 107 ft. long and 6 ft. in diameter, back and forth through which a car seating ten persons was propelled by air pressure. The device was a large-scale example of pneumatic dispatch, such as is now extensively employed, using small metal tubes, for transporting mail matter, telegrams and small parcels. The Beach Pneumatic Underground Railway Co., chartered in 1868, was an attempt on the part of Mr. Beach to establish his system of transportation on a practical scale for city passenger traffic, and he actually constructed some 200 ft. of 8-ft. tunnel from Warren St. north under Broadway. This tunnel still remains as the builder left it. It is more important to note, however, that Mr. Beach invented a shield, with which he constructed his tunnel, and which was the first tunnel shield used in America. It may be worth while also to recall the fact that Beach's shield is the third device of its kind to be actually used in tunnel construction, it being antedated only by the first Thames Tunnel shield of Brunel and the London Tower Tunnel shield of Barlow and Greathead.

The Brunel tunnel patent dates back to 1825. It may be added, however, that the work done by Mr. Greathead in constructing the City & South London Ry. in 1886-89 marked a long step in advance in soft ground tunneling. In that tunnel, compressed air was used to exclude water, in passing through porous ground, the shield was driven forward by hydraulic rams, and the now well-known system of tunnel lining with cast-iron segments was fully developed. In a paper by Mr. Greathead himself (Eng. News, Nov. 5, 1887, p. 325) he said:

A somewhat similar mode of construction was employed in 1868-9 in executing the little tunnel under the Thames at the Tower, originated by the late Mr. Peter Barlow, and carried into execution by the author. There, however, hydraulic and pneumatic power were not employed, and the area of the tunnel was considerably less than half the area of each of the present tunnels. In the interval between that work and this, several not very successful attempts have been made in America to construct brick-lined tunnels with shields of similar construction to the one used at the Tower.

—Ed.]

Notes and Queries.

In the letter of Mr. Garret L. Schuyler printed in our issue of Oct. 21, 1909, p. 439, under the title "Part of a Beam Stronger than the Whole," an error in the drawing Fig. 1 showed the curve of I/y returning to the axis at C. This is obviously incorrect, as the value I/y never returns to zero, although as shown in Mr. Schuyler's letter it may decrease from a maximum value to a lower value. The drawing should show the curve terminating about at the point D.

MOVING A BRIDGE OVERLAND was resorted to at Marietta, Whatcom County, Wash., a few weeks ago. The river channel had shifted nearly a mile to a new location, leaving a steel county bridge 160 ft. in span useless. The problem was how to get the bridge to the new channel. The contractors wanted to take down the bridge, transport it in sections and re-erect it. The County Engineer, Mr. C. A. Lindbery, of Bellingham, Wash., decided that the span should be moved as a whole. Accordingly it was jacked up, blocking and timber sills put under it, and moved along the county road on rollers with the help of horse capstans and double blocks. The span weighed about 40 tons, and the distance it had to be moved was 3,200 ft. The speed of moving averaged 300 ft. per day; one horse was used. The piers in the new channel having been prepared, the bridge was hauled out into place on temporary falsework in two days without hitch. The total cost of moving was only about $700. The men employed in the work had practically no experience with bridges, yet the result was very satisfactory.

Street Railway Track Construction and Paving.*

The Use of T-Rails in Paved Streets.

Your committee recommends the use of T-rail for track construction in paved streets, except where the traffic is confined to the railway strip or is so congested that the strip is continually used by vehicles. Such conditions exist only in cities of the largest class, and here it is the opinion of the committee that a rail of girder section should be adopted, preferably sections following closely the lines of the two Trilby (semi-grooved) rails recommended by this committee in 1907. In this section the rail was made coincident with the wheel loading, 7 ins. and 9 ins. in depth; it was provided with a deep, roomy, self-cleaning groove, that incidentally does not increase power consumption, besides a substantial, heavy, beveled head to suit the street paving, and which allows a maximum wear.

This committee wishes to condemn the adoption and use of so many types of rail as are at present in vogue, whether they be of girder or T-section, where no appreciable benefit may be shown; these undoubtedly increase the cost of manufacture and cost of maintenance, besides creating considerable inconvenience. Certainly the girder sections recommended satisfy the general requirements of modern practice, and no improvements have been suggested up to this time that appeal to the committee as warranting a change in the proposed standard. It is recognized that unusual conditions occur that necessitate the use of types varying from the standard. Both types of girder rails mentioned have practically the same head or wearing part, but although the low rail (especially with the welded joint) has an advantage for stability, it is understood that it is not as desirable as a 9-in. rail where a mechanical joint is used.

Again, the particular type of paving in use should be carefully studied before specifying the height of rail. So it is not in the province of this committee to point out a definite rail section and height without knowing the particular conditions on the property in question. But it should not be a difficult matter to select a standard rail as long as the general principles recited above are taken into consideration.

RECOMMENDATIONS.—(1) For track construction where the type of pavement will permit, as in macadam or other shallow pavement, your committee recommends the adoption as standard of the T-rail weighing not less than 80 lbs. per yd. adopted as "recommended practice" by the American Railway Engineering and Maintenance of Way Association, 1908.

(2) For track construction for the heaviest service in connection with deep block pavements, your committee recommends the adoption as standard of a T-rail 7 ins. high with a 6-in. base, 17/32-in. web and a head of 2⅝ ins. wide and $1^{11}/_{32}$ ins. deep, weighing about 100 lbs. per yd., as shown in Fig. 1.

(3) For track construction for light service, in connection with deep block pavement, your committee recommends the adoption as standard of a T-rail 7 ins. high with a 6-in. base, 7/16-in. web and a head $2\frac{1}{2} \times 1^{9}/_{32}$ ins., and weighing 80 lbs. per yd., as shown in Fig. 2.

(4) For track construction for heavy service in connection with deep block pavement on streets where the traffic is confined to the railway strip, or is so congested that the railway strip is continually used by vehicles (such conditions as exist only in cities of the largest class) your committee recommends the adoption as recommended practice of the half-grooved (or "Trilby") section recommended in 1907.

Open-Hearth and Manganese Steel Rails.

The use of open-hearth standard T-rails has been quite prevalent for some time, particularly abroad. In view of the fact that this subject has been very thoroughly investigated by steam railways, we recommend as standard specifications for such rails the specifications adopted by the American Society for Testing Materials, which are substantially those in use by the different manufacturers.

The use of open-hearth steel for high T and girder rails has not been sufficient to warrant the recommendation at this time of standard specifications. We suggest that the specifications now followed by the manufacturers be used until further developments warrant the preparation of standard specifications.

The use of manganese steel in special work is quite common, but its use in rails has so far been confined to locations where the conditions are unusually severe. The only specifications for manganese steel rail that we have been able to obtain are those of the Manganese Steel Rail Co.† Other manufacturers of manganese steel rails state that they have no specifications that they are willing to publish. We consider that while the use of this type of rail has given in some instances very satisfactory results, it is still in its infancy, and the adoption of any standard form of specification must await future developments.

Of 33 companies only 13 have open-hearth rails in service (113.8 miles). Only one has manganese steel rails and its report is as follows:

The manganese rails (outside of specials) are of 85-lb. section. The rolled manganese rails have been in use since November, 1908, and the cast manganese rails since 1902. Cast manganese-steel rails were 54 times as long as Bessemer-steel rails on a curve having a center radius of 89 ft.

Holes for the bonds in the rolled rails are punched and drifted to size by the manufacturer. Those in cast rails are made by casting pieces of iron pipe in the rail, these being reamed to size. The bond terminals are compressed into the holes.

Track in Paved Streets.

The 40 companies replying to the circulars of enquiry represented 4,085 miles of single track, 2,180 miles in paved city streets, 1,174 miles in unpaved city streets, 435 miles of T-rail track of modern construction in paved streets and 645 miles of track of modern construction with grooved and half-grooved rails in paved streets. Of these companies, 7 are using ordinary railway T-rails of 70 to 100 lbs. per yd., 26 are using T-girder rails 6 to 8 ins. high, and 24 are using grooved girder rails 6 to 9 ins. high.

EXPERIENCE WITH TRACK.—Practically all agree (1) that heavily loaded vehicles can turn out from the flangeway along the rails now being used in modern track construction as easily as or better than from rails formerly used, (2) that vehicles are not damaged in crossing or turning out from said tracks, and (3) that the rail now being used is considered by city engineers or highway officials to be as satisfactory for wagon traffic as any rail in service.

The T-rail track and paving is satisfactory to 30 companies; unsatisfactory to 2 companies, and 8 companies did not answer the question.

The grooved rail track and paving is satisfactory to 13 companies; unsatisfactory to 11 companies, and 16 companies did not answer.

The T-rail track and paving is reported satisfactory to city authorities by 26 companies; unsatisfactory to city authorities by 2 companies, and 12 companies did not answer.

The grooved-rail track and paving is reported satisfactory to city authorities by 19 companies; unsatisfactory to city authorities by 2 companies, and 19 companies did not answer the question.

STANDARD RAILS FOR PAVED STREETS.—Recommendations for a standard rail for use in paved streets were made as follows by 31 companies:

13 favor a 7-in. T-girder rail for all conditions.
6 favor half-groved ("Trilby") or grooved rails 7 to 9 ins. high where vehicular traffic is very heavy, and T-rail in outlying districts where this traffic is light.
6 favor half-grooved ("Trilby") or grooved rails 7 to 9 ins. high for all conditions.
6 favor standard or other sections of T-rail.

The height of rail recommended was 7 ins. by 15 companies, 9 ins. by 8 companies, and various heights by 6 companies; (10 did not answer).

PAVING.—Of 37 companies, 19 are required and 18 are not required to use the same kind of paving in the tracks as is used in the other part of the street. The type of paving considered as the best practice is tabulated below for heavy and light vehicular traffic on both tee-rail and grooved-rail tracks; the miscellaneous types include asphalt, macadam, concrete, Hassam block, slag brick and Belgian block.

Paving.	No. of companies recommending. For heavy vehicular traffic.	For light vehicular traffic.
Granite block	11	15
Brick	11	3
Wood block	5	3
Bitulithic	..	2
Miscellaneous and unanswered	13	17

Opinions of City Engineers, etc., as to Street Railway Track Construction.

ST. PAUL, MINN.—(L. W. Rundlett, M. Am. Soc. C. E., Commissioner of Public Works).—In relation to the rail section to be used for street car traffic, in my opinion, the T-rail best suits all conditions. In the first place, I think it is the best rail that can be put down, looking at it from the street car standpoint, and I am of the opinion that in paved streets the pavement can be so laid that it gives equally satisfactory results, as far as the city is concerned, as the grooved rail.

On unpaved streets it causes no more obstruction than the grooved rail. It is evident that teams can be driven along the line of the grooved-rail better than on the T-rail; but that is not the result desired by a city, as what we expect of the street car companies is rapid transit, and we do not wish to invite any team traffic along the tracks to obstruct them. We have never experienced any trouble with the tracks as laid in this city on the paved streets, and have never received any complaints either from teamsters or from the public in general; I do not think there is any particular difference whether the traffic is light or heavy.*

The construction of the pavement between the tracks and on the outside of same must be first-class when the T-rail is used, and the same thing might be said of any rail.

In regard to the height of the rail, it must be sufficient to give ample room to put in the pavement on paved streets, and the 7-in., 91-lb. standard rail which is used by the street car company at the present time is perfectly satisfactory. On streets where there is no pavement, a 4-in. rail has been found sufficient.

MINNEAPOLIS, MINN. (Andrew Rinker, City Engineer).—The T-rail not less than 7 ins. deep is recommended for use in paved streets under both heavy and light vehicular traffic, as its form admits of a better construction of paving. As to T-rails and grooved rails, the former do not interfere with vehicular traffic, and afford millions of patrons of a street railway company better facilities for rapid transit than the use of a grooved or flanged rail.

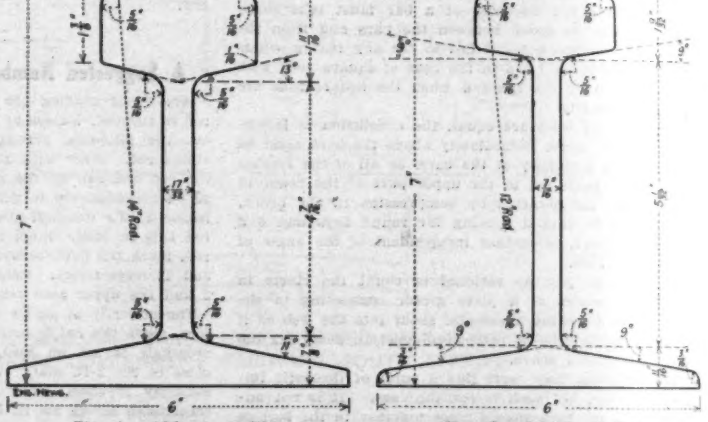


Fig. 1. 100-Lb. Rail for Heavy Traffic.

Fig. 2. 80-Lb. Rail for Light Traffic.

RECOMMENDED SECTIONS OF 7-IN. GIRDER RAILS FOR STREET RAILWAY TRACK IN PAVED STREETS.

For paving T-rail track where vehicular traffic is heavy, generally speaking the best practice is to use a dressed granite block paving properly laid in the space occupied by the street railway track or tracks. The height of rail should be not less than 7 ins., as the paving can then be more satisfactorily laid flush with the top of the rail without interference with the construction.

UTICA, N. Y. (Arthur O'Brien, City Engineer).—The best rail section for paved streets with heavy vehicular traffic is a T-rail of sufficient height to allow proper depth of pavement, as this is more rigid and has less tendency to lateral movement than a girder rail. A 7-in. rail is satisfactory. The same applies to paved streets in outlying districts where the vehicular traffic is light, except that a rail of less height may be used, as a lighter pavement will be required. For paving with T-rail (or girder-rail) the best practice is to use granite or sandstone block where the vehicular traffic is heavy. Where this traffic is light, vitrified brick is best; it costs less and has a better appearance.

PITTSBURG, PA. (N. S. Speagel, Superintendent of Bureau of Construction).—For paved streets (with both heavy and light vehicular traffic) the rail recommended is the grooved girder rail, having the lip level with the top of the head. The grooved section offers less obstruction to wagon traffic, permits of better paving construc-

*Abstract of a report of the Committee on Way, presented at the annual convention of the American Street and Interurban Railway Engineering Association at Denver, Colo., Oct. 4 to 8.

†These are for rolled rails, and give the chemical composition as follows: Carbon, 0.90 to 1.20%; phosphorus, not over 0.10%; silicon, not over 0.50%; manganese, 9.50 to 16%; sulphur, not over 0.06%. The rolled manganese-steel rail is a very recent development. The manganese-steel rails which have been used on sharp curves of street and elevated railways for several years are cast to shape, and are very hard and expensive, but have an extraordinarily long life under curve wear.—Ed.

*This track has 7-in., 91-lb. T-girder rails, with 6-in. base and 2¾-in. head. They rest on oak or pine ties 2 ft. c. to c.; the ties are 6 × 8 ins., 8 ft. long, laid on a concrete base, and with concrete filled level with their tops. The rails have cast-welded joints. Granite blocks 4½ to 5½ ins. deep are laid between the rails and tracks (set ¾-in. lower than the rail head), the blocks against the gage side of the rail being nose blocks which form the flangeway and fit under the rail head. The blocks are laid on a sand bed. Where brick, stone or wood paving is used for the sides of the street, it is laid against the rails; but where asphalt is used, a line of stone stretcher blocks is laid against the outside of each outer rail. The tracks are 10 ft. c. to c.—Ed.

tion adjacent to the rail, and consequently lessens the cost of pavement maintenance. Where concrete is used under the ties and between the rails, the necessity for the use of the grooved section becomes less imperative. The track construction of this city consists generally of 9-in. girder rails laid on wooden ties on a 6-in. foundation of broken stone. Where asphalt is laid, a row of block stone stretchers is laid outside of the rail.

As to T-rails and grooved-rails, the T section offers more obstruction to traffic, causing unnecessary wear on the pavement adjacent to the rail, with consequent ruts and depressions. The cost of the pavement is greater also, on account of maintenance. The advantage of the grooved rail is the ease with which traffic can turn out of the track; it has also a tendency to distribute vehicular traffic over other portions of the street, and permits of better pavement construction adjacent to the rail.

The best paving where vehicular traffic is heavy is creosoted wood block (on 6-in. concrete base) with grooved rails, or stone blocks with T-rails. Where this traffic is light, the best paving is repressed vitrified brick or sheet asphalt with grooved rails, and the same kind of brick (on 6-in. concrete base) with T-rails.

WASHINGTON, D. C. (Capt. E. M. Markham, U. S. A., Assistant Engineer in Charge of Highways).—For paved streets under both heavy and light vehicular traffic, the rail recommended is a grooved girder rail with 1-in. groove, or a semi-grooved ("Trilby") rail with 1¼-in. groove, as this section best enables the paving to be kept flush with the rail head and gives a minimum interference with the wheels of vehicles. The T-rail on paved streets cannot be made as satisfactory to traffic as the grooved rail. The best paving with grooved rails where the vehicular traffic is heavy is wood, scoria or Hassam blocks; the same applies where the traffic is light, but with the addition of asphalt with blocks laid along the rails.

Widening Gages on Curves.

The 32 replies received to a circular of enquiry on this subject show a considerable variation in the practice of increasing the width of gage. However, in the majority of reports the general practice is shown to be that of increasing the gage for curves varying from 100 ft. to 35 ft., center radius, from neat gage to plus ¾-in.

The advisability of increasing the gage of curves certainly depends on the radii, dimensions of wheel and flange, length of wheel base, and the size of groove of guard rails. On account of many companies being burdened with cars of different types, and it not being practical to change the size of the throat of guard rails for varying radii, it follows that the extreme conditions must be taken care of. This probably accounts for the greater number of reports showing an increase of gage on curves.

The committee has also investigated the proper height of a tee-rail guard as compared to that of rolled guard, and it is its opinion that in tee-rail work it is preferable to place the tee guard-rail ½-in. to ⅝-in. higher than the running rail, as against ⅝-in. for the rolled guard. This increase in height is necessary on account of the beveled edge or rounded corner of the tee-rail.

The "Question Box" included some matters relating directly to the subject of this report, and these we append below:

Cost and Life of Steel Ties.

We place steel ties 4 ft. c. to c.; they cost $1.76 each, with fastenings. Wooden ties are 3 ft. apart and cost 76 cts. each. Steel ties should last 20 years at least and then have a scrap value of almost 50% of first cost. Scrap value of wooden ties would be from 2 to 10 cts.

Utica & Mohawk Valley Ry.—One steel tie (Carnegie, 14½-lb.), costing $1.77, replaces three wooden ties 6 × 8 ins., 8 ft. long, spaced 24-in. centers, costing $2.18. Excavation with steel ties, 4.2 cu. ft. per ft. of track; with wooden ties, 8.5 cu. ft. per ft. of track, an increase of 8 cts. per ft. of track when excavation costs 50 cts. per cu. yd. Track laying and surfacing with steel ties costs 20 cts., as compared with 50 cts. per ft. with wooden ties on stone ballast that generally requires two (and in places three) tampings. Assuming top of concrete at base of rail, with steel ties concrete extends only 6 ins. below rail, except that the concrete beam 12 ins. wide extends 6 ins. under tie; if 6-in. concrete is placed under wooden ties, about 2 cu. ft. per ft. of track would be required in excess of concrete for steel ties. At $4.50 per cu. yd. this amounts to 33 cts. per ft. of track. Two spikes per foot of track, costing 3 cts., are saved. The total saving for single track with steel ties is thus about $1.13 per ft. Steel ties should last at least as long as the best wooden ties.

Wear of Gage Lines of Rails on Tangents.

Utica & Mohawk Valley Ry.—Both rails should wear equally on gage lines if rails are surfaced level and motors are suspended alternately on right and left sides. The leading wheel of a car on the gear side generally shows more wear than the other wheels, as the driving force is exerted at an oblique angle to the rail, being more noticeable when gear and pinion become worn. This tends to wear the rail on that side, but suspending motors alternately should prevent unequal rail wear. Heavy wagons wear gage in turning out to the right from double tracks. Passengers are liable to sit on right side of car, thus bringing heavier loads on outside rails of double tracks.

Washington Ry. & Electric Co.—The gage line of both rails on straight track usually wears equally if the track is in perfect line and surface. Otherwise, the tendency is for cars to shift from side to side, causing unequal wear of the gage lines of rail heads.

Schenectady Ry. Co.—On city track in pavement the outside rail (double-track) shows excess wear over inside rail due to the former being set ½-in. lower than the latter to conform to the street contour. This track has 7-in. and 9-in. girder rails, with concrete ballast and sand foundation. Both rails are bonded.

Creosoted Wood Block Pavement.

Cost and life of creosoted wood block paving on concrete foundation are given as follows: Washington, $3.25 per sq. yd.; only in use three years. Baltimore, $3.55; none in use more than four years, but that is apparently in as good condition as when laid. Utica, $3.45 per sq. yd., on 6 ins. of concrete. Newark, N. J., $2.75 per sq. yd.; 14 years.

Another street railway company reports $5.50 per sq. yd. with concrete beam under the rails and concrete to bottom of ties; $4.50 per sq. yd. with concrete to bottom of tie under the rails and 6 ins. of concrete under the balance.

Spacing of Ties.

As to the proper spacing of ties 8 ins. × 8 ft. in track laid with 6 ins. of crushed stone under the ties and 4 ins. of concrete between them, the street railway companies of Baltimore, Syracuse, Utica, Schenectady and Kingston (N. Y.) report ties 2 ft. c. to c. At Washington, the spacing is 30 ins.

Setting of Concrete Foundation.

The replies to an enquiry as to the time allowed for the setting of concrete under and between the rails before allowing cars to run over the track, show a great variety of opinions. Kingston (N. Y.); with proper precautions it is not necessary to stop cars to allow concrete to set. Schenectady; not less than 4 days. Utica; at least one week. Syracuse; 10 days at least, and longer if possible. Newark; 7 days. Baltimore; 3 to 7 days, depending on the equipment and the traffic conditions. Washington; 15 to 20 hours if the concrete mixture is strong enough and the weather is favorable.

Life of Rail Joints on Paved Streets.

Washington Ry. & Electric Co.—We have some cast-weld joints which were placed on new rails laid ten years on slotted track supported on cast-iron yokes 5 ft. c. to c. They will last probably as long as the rails.

United Rys. & Electric Co. (Baltimore).—From our experience, cast-weld joints and electrically welded joints should last as long as the rails. Our experience with mechanical joints has not been entirely satisfactory, as in almost all instances the paving has to be opened and the joints tightened in the course of 3 or 4 years. We have therefore adopted electrically welded joints as our standard.

Southern Wisconsin Ry. Co. (Madison).—Our cast-weld joints on 72-lb., 6-in. tee-rails are in good condition after four years' service under 12-ton cars running on a 10-minute schedule. The life of the mechanical joints is about six years; we expect to cast-weld these joints.

Schenectady Ry. Co.—The life varies according to car movements. Cast-weld joints from tee to girder-rails installed in 1904 on lines with 7½-minute schedule have an estimated life of ten years. Special mechanical joints have failed in from three to five years. We have no electrically-welded joints on new rails; of 1,325 joints welded in September, 1905, about 1% have developed breaks up to June, 1909.

Utica & Mohawk Valley Ry. Co.—The Clark joint and other good makes of mechanical joints, when properly installed and surrounded by concrete and pavement, should last as long as the rails.

Efficiency of Electrically Brazed or Soldered Rail Bonds.

United Rys. & Electric Co. (Baltimore).—Soldered bonds placed on the outside of rails in streets graded to the top of the ties have proved most unsatisfactory, and have been replaced by the twin plug terminal exposed bond, also fastened to the head of the rail, which has given excellent results.

Utica & Mohawk Valley Ry. Co.—We have no brazed bonds. Soldered bonds have proved unsatisfactory in test made with five different makes placed on outside of head of 65-lb. tee-rail. Out of a total of 444 bonds, placed in 1907, 83 were off, 64 were loose at one end, and nine had defective strands, in February, 1909. Some of these bonds, among them those giving poorest results, were placed by representatives of the makers.

For detecting defective rail bonds in paved track, several railways report the use of voltmeters or a special test car (such as the Herrick car) as most satisfactory. Hand instruments measuring joint resistance in comparative length of abutting rails (indicating conductivity of bond as compared with a certain length of rail) are fairly satisfactory.

Discussion.

The discussion of the report of the Committee on Way was very brisk and extended, and we give herewith a summary of the remarks and opinions presented, classifying this by subjects for the purpose of convenience.

RAILS.—Mr. Charles H. Clark (Engineer of Maintenance, Cleveland Rys.) approved of the recommendation of a 17/32-in. web for a 7-in. tee-girder rail. In many cases the thickness is ⅛-in. or less, which is insufficient, and the vibration due to the thin web is one cause of rail corrugation. He also approved of the recommendation of tee rails in paved streets, except, perhaps, in large cities where a heavy teaming traffic follows the rails and will wear ruts in the paving unless granite blocks are used. The Cleveland 7-in. grooved rail has a 3-in. head and ⅜-in. groove, the guard being ½-in. below the level of the rail head. The side of the groove projects about ⅜-in. toward the pavement on account of automobile wheels. He favored a wider tread for car wheels, which would require a wider rail head, and it is for this reason that he uses a 3-in. head. Mr. George Weston (Chief Engineer of the Board of Supervising Engineers, Chicago) thought that engineers experienced in track construction and maintenance would generally prefer the T-rail, if the pavement could be made to stand team traffic. In Chicago, however, the ordinance requires a grooved rail, although for some of the outlying streets the Calumet & South Chicago Ry. has been permitted to use a tee-rail construction subject to the approval of the Board. Where T-rails have been used hitherto in Chicago, it has been in connection with brick paving and nose brick, but heavy wagons tend to abrade or break down the edge of the groove. He preferred laying ordinary brick with the ends under the rail head and the middle crowned to a level with the top of the rail, as at Milwaukee. As to open-hearth rails, the Chicago lines have found less breakage of electrically welded joints in these rails than in Bessemer steel rails.

Mr. W. H. Evans (International Ry., Buffalo) referred to Denver as the pioneer city in the use of T-rails for paved streets. He did not consider it essential to have the rail head as wide as the wheel tread, but the tread should always be as wide as the rail. The tread width should be not less than 3 ins. Many companies have to accommodate cars having wheels of such form as to be permissible on steam railways. Mr. R. C. Cram (Assistant Engineer of the Connecticut Rys.) favored the T-rail, though several cities in which his company has lines require the use of grooved rails. They are generally laid on concrete stringers, and the maintenance of the joints is more difficult than with grooved rails. As to width of rail head, he considered 3 ins. unnecessarily wide. Mr. Victor Angerer (Wm. Wharton, Jr., & Co.) favored a thick web and a wide head. A great difficulty with grooved rails is the great variety in wheelbase and in form of wheel and flange of the cars that run over the tracks. Thus a form of groove that may be eminently satisfactory in one case is not so in another case, but it is not practicable to roll rails of forms to suit all cases. In the width of gage on curves, also, there is trouble, and in some cases where special work is built for standard gage the local trackmen pull it apart to widen the gage. When the curve is such that the groove will not accommodate the wheel flanges, the groove is planed wider. His practice is to plane the head of the inner rail and the guard of the outer rail, thus preserving the full thickness of the guard of

the former, but some engineers specify planing the guards of both sides.

Mr. M. Schrieber (Engineer of Maintenance of the Public Service Ry., Newark, N. J.) pointed out that the introduction of the T-rail requires the consent and cooperation of municipal engineers, and it is for the railway engineers to convince the former of the advantage of this type of rail. It is also of great importance to adopt standard sections and to gradually eliminate the multiplicity of special sections which have no advantages commensurate with the expense and inconvenience incidental to their use. Standard rails can be obtained at a lower cost and with more prompt delivery. Mr. Ackerman (Columbus) did not consider it necessary to use a rail wider than 2¾ ins. in the head.

TIES AND FOUNDATION.—Mr. C. H. Clark (Cleveland) stated that steel ties are now standard for track construction in Cleveland, and are in fact required by the city ordinance. A 10-in. bed of concrete is laid under each rail, and in this the ties are embedded, while the space between is filled with earth, so as not to require more than 5 ins. of concrete for the paving. Mr. Weston (Chicago) stated that in the earlier designs for track reconstruction in the Chicago streets provision was made for a greater depth of concrete under each tie. In practice, however, it was found that the workmen walking over the work broke down the earth so as to partly fill the deeper excavations at the ties, and these had to be cleaned out again for the concrete. It was decided that it would be better to excavate to one level and then roll the foundation (which cannot be done under the other plan), making the concrete of uniform thickness.

In Chicago, there is a permanent foundation of concrete, in which are embedded the ties; these ties are treated with chloride of zinc, as this preservative will not leach out of the wood when it is embedded in concrete. Steel tie-plates are attached to the ties by small lag screws independent of the screw spikes, so that should the rail have any movement upon the plate, it will abrade the plate only and not cause the plate to move and abrade the tie. Mr. D. N. Brondson (Providence, R. I.) stated that his present practice is to put the ties not more than 2 ft. apart, to provide against any springing or wave motion in the track. Mr. Schrieber (Newark, N. J.) considered stone ballast equal to concrete under the ties. He rolls the subgrade, lays a bed of broken stone, places the ties upon this and then fills in concrete between the ties. The stone ballast provides for drainage. For treating ties, he places them first in an open tank of hot material (creosote or carbolineum) and then in an open tank of cold chloride-of-zinc. This is the opposite of the Card process, in which the creosote was applied after the chloride.

Mr. A. E. Bong (Salt Lake City) is using ties treated with carbolineum. After five years service these are in good condition, while untreated ties had decayed. Mr. E. O. Ackerman (Columbus Ry. & Light Co.) had laid oak ties in concrete, covering them to a depth of 1½ ins. He had expected this would preserve them, but on opening the track this year (after eight years) he found many ties decayed. He attributed this to the thin covering of concrete cracking so as to admit water, which could not then escape. In 1897, he laid a track of 7-in. T-rails on concrete longitudinals 15 ins. wide and 18 ins. deep; these were 16 ft. long and with 2-ft. spaces between their ends. Anchor bolts were embedded in the concrete, and when the rails were bolted down a thin grout of cement mortar was filled around the base of the rail and over the bolts. This track is still in perfect condition, due largely to the secure hold of the anchor bolts, especially in holding the rail ends.

PAVING.—Mr. Weston (Chicago) stated that with paving on concrete, in spite of grading and tarring the joints the water would work in and cause the paving to rise. Mr. Clark (Cleveland) considered that drainage is essential to prevent such trouble. He places a 6-in. drain of vitrified sewer pipe between the tracks and 12 ins. below the ties, buried in cinders, which material is better than gravel or stone for this purpose. At intervals of 50 ft. a manhole 12 × 12 ins. is left in the concrete, this being filled with broken stone over the pipe. Mr. Weston has found that grout filling will crack and separate from the rail even on the most substantial track, this being due to the vibration under traffic. Mr. Schrieber has tried a ¾-in. strip of hot asphaltic cement laid alongside the rail head. Mr. Ackerman (Columbus) finds that paving blocks will rise along the rails during the first year, under the influence of vibration, but after that the trouble is very much less. In regard to granite nose blocks forming the grooves along track laid with T-rails, Mr. Schrieber said that it costs 6 cts. for cutting each block, or 36 cts. per ft. of track. Blocks of Medina stone are used in some cities, but will wear in ruts if the traffic follows one line.

The Protection of Railway Signals and Electric Railway Lines Against Lightning.*

Lightning Arresters for Signal Protection.

The usual method of protecting signal appliances from lightning in the past has been to install spark-gap arresters (usually of the "saw-tooth" type) between the line wires and the ground on each side of, and close to, the relay or other device to be protected as shown at S S in the accompanying figure, in which R is a relay, the contacts of which it is desired to protect.

It has also been common practice to insert reactance or choke coils in the circuit between these spark-gap arresters and the instruments to be protected, as shown at C C, on the theory that the inductance of these coils would resist the sudden rush of current which takes place over the line when a lightning stroke occurs in the neighborhood, damming this current up in front of the choke coils, so to speak, until the electromotive force becomes sufficiently high to break across the spark gap S S to earth.

Quite frequently grounded brass strips P P, placed in close proximity to the choke coils, are used to provide a path for the discharge from the choke coils themselves to these strips and thence to earth.

The use of fuses is generally unpopular because the blowing of a fuse puts the signals affected out of commission until a new fuse is installed, and also because it has been found that fuses sufficiently sensitive to afford protection are often burned out by discharges that would have caused no damage, thus increasing the number of unnecessary failures of the signal system and consequent delay to traffic to an extent that is intolerable. Fuses are therefore seldom used.

Whether lightning arresters are needed for the protection of relays and other instruments connected to the rails of the track has always been a disputed question. Sufficient evidence of damage to such instruments by static discharges from the rails has been obtained to satisfy the committee that lightning arresters should be used in these circuits, as well as in the line wire circuits wherever atmospheric electrical disturbances are comparatively frequent or severe, and reasonable immunity therefrom is desired.

Various methods of grounding arresters have been tried but the best results seem to have been obtained either by driving an iron pipe into the ground or burying a copper plate 2 ft. or 3 ft. square, and embedding it in coke or charcoal.

When a thunder cloud approaches the line wires, a static charge is induced on the latter higher than that of the ground. This difference of potential between the line wires and the earth may increase until it is sufficient to puncture the insulation of the relays and other devices at which these line wires terminate when a discharge will occur through these instruments with disastrous results. The electrostatic stress in the line could be relieved by providing a permanent leak, such as a high resistance connection between the line wires and the earth, but such a leak would be liable to interfere with the proper working of the signal circuits in other ways.

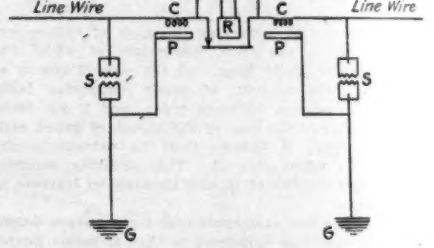
Spark-gap arresters connected between the line and the earth will prevent the static charge on the line reaching a dangerous pressure if the spark gap is made small enough to offer less resistance to a discharge than the insulation of the relays and other devices to be protected. The difficulty encountered in attempting to do this is that small particles of metal, cinders or other conducting materials are apt to lodge in the spark gap thereby permanently grounding the line which is liable to seriously affect the proper working of the signals, or, if the spark gap is made by mounting two metal plates a very small distance apart as in the ordinary saw tooth arrester, the discharge may fuse these two plates together. Even moisture between the plates may ground the circuit sufficiently to interfere with its safe working. The spark gap should therefore be so designed as to prevent the permanent grounding of the circuit from any of these causes.

Another difficulty experienced with the saw-tooth arrester is the burning off of the serrated edges, thus widening the spark gap and increasing its resistance. Certain other substances, such as carbon, acquire a high resistance coating as a result of static discharge and are therefore unsuitable for use in lightning arresters for signal circuits which should be capable of discharging repeatedly with unvarying efficiency.

With the low voltages used in automatic block systems and the electric locking and annunciator circuits of interlocking plants there is no danger of the battery current continuing to flow across the spark gap after the discharge, but in arresters intended for use on the control wires of electric interlocking plants, or on storage battery charging lines, some means of extinguishing the arc started by the lightning discharge must be provided. All of the lightning arresters designed for the protection of electric light and power lines are provided with some means of accomplishing this, usually by cooling, or smothering the arc, or by means of a magnetic blow-out, or by the use of a non-inductive resistance in series with the gaps.

For relieving steady electrostatic pressure on the line probably the best arrangement of the spark gaps would be to space them at equi-distant intervals along the line. But when a lightning discharge occurs from one cloud or part of a cloud to another or to the earth in the neighborhood of the line, the electrostatic charge on the line readjusts itself to the new conditions by an oscillation or impulse seeking a path to the earth.

It is to assist in taking care of disturbances of this kind that the choke coil is of value and this value seems to be unquestioned provided the coil has sufficient inductance. A coil 12 or 15 turns, however, has so little inductance as to render it, in the opinion of the committee, practically worthless. The committee is also inclined to doubt whether the use of an iron core is of any value in increasing the inductance of the coil as the iron would not have time to become magnetized. Ground plates set to receive discharges direct from the choke coils as shown at P P in the diagram are of no value unless they are placed very close to the coils and if this is done a great deal of trouble is experienced from the coils coming in contact with the plates and permanently grounding the circuit. The use of such plates is therefore inadvisable, judging from the results of experience with arresters of this type which have been reported to the committee.



Typical and Faulty Installation of Lightning Arresters on Railway Signal Lines.

It has been suggested that, where two line wires approach a relay or other instrument from opposite directions as is frequently the case, a spark gap placed across the instrument as shown at B in the diagram might afford considerable protection by permitting discharges to proceed uninterruptedly along the line wires until they gradually dissipate or find a harmless path to the earth.

Another form of protection, which has been suggested but, so far as the committee has been able to learn, has never been tried in connection with any signal installation, is the grounded overhead wire utilising the principle first advanced by Faraday that a grounded metal cage enclosing the line wires or any other structure to be protected would afford the most complete protection possible against lightning.

One or more grounded overhead wires have been used for protection of a number of long-distance power-transmission lines with various results, the experience on the whole seeming to indicate that such wires properly installed would afford considerable protection. One of the most important requisites of such a protective wire is high conductivity. Wire of ample size should be used and thoroughly grounded at frequent intervals. At first barbed wire was used, but this gave considerable trouble from frequent breakage and it was found that plain galvanized iron wire was equally effective so far as protection was concerned. The results of some experiments indicated that such a wire was equally effective when strung below the line wires as when strung above them, but the best authorities recommended putting the pro-

*Abstract of a report of a special committee of the Railway Signal Association, presented at the annual meeting at Louisville, Ky., Oct. 12 to 14.

tective wire over the line wires and high enough to form an angle not greater than 45° with the outside wires.

The grounded overhead wire is probably the best protection against direct strokes of lightning that can be provided. The ordinary lightning arrester will not take care of direct strokes, but fortunately such strokes are rare, the discharge usually occurring between one cloud and another, or from a cloud to the earth, or between different parts of the same cloud, and in such cases the lightning arresters only have to take care of the disturbances caused in the circuits due to the induced charge on the line wire.

It is probable that poor ground connections are really responsible for more lightning trouble than inefficient lightning arresters. It is not only necessary to select a suitable spot for the ground plate (in permanently damp earth if possible) but the connections from the arresters to the ground plate should be as short and straight as possible. Sharp bends in ground connections should be avoided and loops or coils should never be allowed on account of their inductance. Some authorities even go so far as to specify that, where a pipe driven into the ground is used instead of a ground plate, the ground wire must be plugged into a cap screwed on the top of the pipe instead of being wrapped around and soldered to the pipe on account of the inductance of this wrapped portion of the wire. Copper wire of ample size should be used for all ground connections, No. 6 B. & S. or larger, being recommended, and every effort should be made to keep the resistance of the path for the lightning from the line to the earth as low as possible.

Lightning Protection for Electric Railway Lines.†

The term "lightning" is now used by many engineers in a most general way to describe surges of potential of a value high enough to approach the danger point. With this viewpoint lightning may be sub-divided into two great branches: (1) internal, or disturbances caused by switching, short-circuits, grounds, etc.; (2) external, or more properly speaking, cloud lightning.

The most common phenomenon of external lightning is manifested as induced static or "bound" charge, and that is practically all that has to be contended with in low-voltage circuits such as railway lines. Consider any overhead line insulated from the ground and suppose a positively charged thunder cloud passes over it. The ground below the cloud assumes an electro-static charge opposite to that of the cloud above, as does also the line, and furthermore, the charge assumed by the line is higher than that of the ground since it projects above it. A flash between cloud and cloud, or between cloud and ground, equalizes the potential existing between them, and requires a change of potential distribution on the line.

This equalization of potential between cloud and ground leaves a free charge on the line which manifests itself now as an abrupt impulse or wave traveling along the line with approximate velocity of light, 186,000 miles per sec. These waves have frequencies corresponding to the discharge frequency of the cloud, and amount to thousands of cycles per sec. Reaching an end of the line, they suffer reflection either from resistance or otherwise, and give rise to complex phenomena. On a line not connected to ground, some provision must be made to supply leakage for waves like these, otherwise the potential will rise until the insulation is punctured.

High e.m.f.'s are caused in a system by means of electro-magnetic induction, since the cloud discharge is a current and sets up an opposing e.m.f. in any parallel conductor.

The phenomenon known as direct stroke probably occurs very infrequently on a system. In case the discharge does strike the line, it is quite possible that small damage to apparatus will result, owing to the choking effect of the line on such an abrupt discharge. The e.m.f. will on this account build up very suddenly and probably jump to the pole and ground itself that way. Shattered insulators and splintered poles are the result. Supposing, however, that the discharge does take place near some apparatus or that sufficient passes along the line to enter the station; in such cases protection will sometimes only be obtained at the loss of the arresters, which then will have certainly paid for themselves many times over.

The original lightning arresters were the product of necessity, a remedy demanded by new conditions. The first electric wires had hardly been strung when lightning troubles began to manifest themselves, and something was necessary to prevent them. The knowledge of lightning and kindred static discharges was extremely limited; even more so than nowadays, when we must confess that our knowledge at best is incomplete. The early lightning arresters therefore were crude affairs, and but few of the early ideas have survived.

†Abstract of a paper by Mr. J. V. E. Titus, Second Vice-President of the Electric Service Supplies Co. (Philadelphia), forming an appendix to the report of the Committee on Power Distribution, presented at the annual meeting of the American Street & Interurban Railway Engineering Association, at Denver, Colo., Oct. 4 to 8.

Originally, efficiency in discharging the circuit was the prime requisite; the other essential to a successful lightning arrester, durability, has come by a process of development. A majority of the users of lightning arresters to-day do not realize that just about half of the efficiency and half of the durability depends upon the manufacturer and the lightning arrester itself; the other half depends upon the user, in the way he installs it, and the care he takes of it after it is installed.

The prevailing practice in the electric railway field has been to install lightning arresters when the line was first constructed, and to equip each car with a lightning arrester before it was put in service. Neither the line arresters nor the car arresters were ever looked at after that date until some trouble with them was reported.

To-day the most progressive roads make it a practice to inspect lightning arresters at least three times per year, preferably in the spring just before the first lightning storms occur, and while the earth is still moist with the winter rains. Another inspection is made in mid-summer when the earth is dry, and at the time when the most severe storms usually occur. This inspection is probably the most important, as it enables one to find out whether the ground connection is as good as it should be after the surface of the earth has become thoroughly dry. The last inspection is made in the fall, after the storms are over for the season. At that time such arresters as have been damaged may be taken down and repaired or replaced.

Particularly at the spring inspection should the connections to rail be investigated. Frequently the connecting wires become frozen in the earth and the vibration of the rails breaks off the wires. Arresters having no visual means of operation are better tested by employing tell-tale papers—the size of the puncture serving in a measure to check up the condition of the arrester and the ground. By employing this plan of a series of inspections, the cost is kept down to a minimum, and the efficiency of the installation is properly maintained.

In installing lightning arresters, and particularly in the method of providing ground connections, there is a woeful lack of standard practice. Until the last year or two the ground connection has usually been made by burying a copper plate or coil in the earth, with which the ground side of the arrester is connected by means of a copper wire. As an original installation this makes an ideal connection, but such grounding has probably caused as many lightning-arrester troubles as any other one element. In most soils, copper rapidly corrodes and usually the resultant salts form a coating around the conductor that is practically an insulator, thereby introducing in the discharge path a high impedance. This not only impairs the discharging efficiency of the installation, but with some types of lightning arresters prevents the flow of sufficient current, following the discharge, to operate the circuit-opening device. The argument has been advanced that such resistance in a ground path is of but small importance because such a ground connection being of large cross-section, offers a multitude of tiny paths or outlets over which the discharge will escape to earth. The fallacy of this argument is apparent when one considers the impedance that is offered a sudden rush of lightning by even a normal amount of resistance. It is quite as important that the ground path be of low ohmic resistance as that the lightning arrester itself should be. Any ground connection must discharge freely or the desired protection against very sudden rushes of lightning will not be secured.

These arguments for a durable, low resistance ground path apply with particular force rather to the more sudden rushes, than to the slight static discharges that are occurring on a circuit practically all of the time. The latter will be discharged through a high resistance ground with a certain degree of satisfaction. Furthermore, such light discharges introduce so small an element of danger as to be practically negligible.

The affect of a high-resistance ground path permits of a quite pertinent analogy, to show the choking effect of such resistance on a lightning discharge. A handful of shot thrown at an angle into a vessel of water would sink at once to the bottom of the vessel; but the same quantity shot from a gun at the same angle would immediately glance off and the vessel would probably be destroyed. In the first case the resistance of the water would not be appreciable because there was no force back of the shot, but in the second case quite the opposite.

The argument that a badly corroded ground plate is still fairly efficient, due to its large cross-section, is based on the claim that the greatly increased surface presents a multitude of tiny paths over which the discharge will scatter to earth. But to refer to our analogy above, it would make but slight difference whether the handful of shot, fired from a gun, struck the water in a vessel or the surface of the Atlantic Ocean. It would not easily penetrate the water.

The use of galvanized iron pipe for ground connections has been recommended for the last year or two with the very best results. In soils that will permit, the pipe may be driven to a sufficient depth to reach permanent moisture. If it is necessary to dig a hole, because of a stony soil, a plate or any chunk of iron may be buried in the bottom of the hole, and the iron pipe tapped into it. In order to make a proper and durable connection, it is usual to put an ordinary iron T just below the surface of the ground on the upper end of this pipe. In the other end of the T screw an 8-ft. or 10 ft. length of pipe that extends upward along the pole. To the upper end of this pipe should be connected the ground wire from the arrester. In the other angle of the T, on railway circuits, a pipe should be screwed that extends over to the rail. The end of this pipe is to be connected with a cross bond or stub-end bond, thus securing a permanent connection with the rail as well as with the ground. All joints and connections should be carefully taped and painted with some preservative paint to prevent corrosion; particularly should the pipe be well painted at the ground line, as here corrosion proceeds at a more rapid rate.

Under some conditions it is not practical to use pipe to secure the rail connection. Rubber covered copper wire, properly taped and painted at exposed joints, should then be used. In some places copper wire in flexible conduit has been used with good results. This method of connecting lightning arresters by means of iron pipe insures the greatest possible durability at a reasonable first cost. Its chief advantage lies in the fact that iron pipe corrodes very slowly in practically all soils, and the resultant salts are fairly good conductors. Even after the pipe has completely wasted away the usual oxide provides a good conductor, unless of course it becomes broken.

An effort should always be made to secure genuine puddled-iron pipe, or the best grade of galvanized steel pipe. Steel pipe, if properly galvanized, presents a more durable and cheaper material than any other product, except puddled-iron.

Some operating officials question the advisability of grounding arresters on railway circuits to the rail, as well as to the ground-point. There are several reasons for a rail connection in grounding lightning arresters. The ideal condition is that at the instant of discharge the line, rail and earth shall be at the same static potential. It is to accomplish this result that the discharge occurs. To secure this end it is absolutely necessary that rail and ground shall be of the same static potential at all times. Great care is usually taken to have these conditions, but on many systems, particularly large interurban properties where rock ballast is used, the rail may be of other potential than the earth at many points.

Let us see what conditions may exist under this circumstance. Let us suppose a rock-ballasted roadbed in mid-summer when the rail is absolutely insulated from the earth for a considerable stretch of track. There is a lightning arrester on an adjacent pole that is properly grounded to earth, but has no connection with the rail. Possibly there was such a connection when the installation was originally made, but, due to corrosion, or breakage at the rail when the ground was frozen, the connection has failed. When a discharge takes place through the arrester, the feeder, trolley and earth are momentarily at the same static potential, while the potential of the rail against earth may reach many thousands of volts. With these conditions, there is every possibility of a discharge from the rail puncturing the windings of the motors of a car that is passing, and going to earth via the car, the trolley wire and the arrester on the adjacent pole. Many a car has been burned in this way, and the arresters criticised when they were not to blame.

The remarks in a preceding paragraph regarding the effect of resistance on a discharge will be pertinent here, as even if the earth is more or less moist and the rails are not completely insulated from the earth, there may be enough resistance in the earth between the rail and the ground connection of the arrester to drive the discharge around through the car motors via the trolley wire to the pole arrester and then to earth. This may have the appearance of an elaborate effort to explain why lightning arresters do not always protect, but there has been advanced most unmistakable evidence that many car motors are burned out in exactly this way.

In choosing a system of lightning protection compromises have to be made. The ideal arrester is of course an insulator between line and ground, such as an air gap which passes absolutely no normal line current when used on a circuit for which it is adjusted. As soon, however, as the voltage of the system rises by even the least fraction above normal, this insulator must break down and afford a path to ground of infinitely low resistance, and as soon as the voltage again reaches normal the insulating properties of our insulator should at once reassert themselves. Such is the ideal arrester. But such an arrester, consisting simply of an air gap, is entirely impracticable, since the voltage of the system is never what one may even call practically uniform. The compromise lies in the fact that the air gap must be adjusted for some point between normal voltage of the system and what we may call the danger voltage at which the insulation of the system is imperiled. The first consideration, therefore, is that an arrester must have an air gap small enough to come between these limits.

Another reason why the simple air gap is unsatisfactory as a lightning arrester is that on a grounded circuit every discharge will necessarily produce a dead short circuit between line and ground. This means not only a loss of energy, but severe and dangerous strains on the apparatus supplying the current. Something must be found that will limit the flow of dynamic current to such a degree that these severe strains and the resulting dangers are avoided, but in limiting this flow of dynamic current we must be careful not to limit or seriously impede the discharge of abnormal voltages.

To solve this problem, resistance, in series with the air-gap, at once suggests itself. Here the limits lie, on the one hand, between a comparatively low series resistance, combined with some circuit-opening device, for instance a magnetic blow-out or circuit-breaker, capable of breaking the flow of current following a discharge to ground, and, on the other hand, a resistance high enough to suppress the rush of dynamic current to such an extent that none or practically none of it follows the discharge to ground.

Here we have another compromise, as the resistance is made comparatively low, only enough in fact to limit the current to a value that can be handled readily by the circuit-opening device. This is the mean between a resistance of practically nothing with the resulting short-circuits and strains on apparatus, and an ohmic resistance of a value high enough to entirely eliminate these strains, but which also impedes the passage of any discharge occurring from line to ground.

The requisites then of a satisfactory lightning arrester appear to be:

(1) A medium, such as an air-gap, which breaks down on a voltage low enough to insure protection to apparatus.

(2) A resistance of a value sufficient to prevent grounding and the consequent strains on apparatus, but not so high as to impede to any appreciable extent the free passage of the more heavy discharges.

(3) Some positive automatic means of interrupting the relatively small flow of normal current following the discharge.

Users are heard even to-day expressing the opinion that a lightning arrester is good for but one discharge. If that were true, then a fuse in series with an air-gap would be the ideal arrester, because it would be entirely efficient for its one discharge, and would be inexpensive. Results, however, have proven quite differently with the more modern types of lightning arresters now on the market.

A large part of the failures of the older forms of lightning arresters, employing a low series resistance and some form of circuit opening device, was due to an increase of resistance of the resistance rod itself.

These rods were usually made of some combination of carbon or graphite with kaolin. Due to the action of the discharge in some cases, and to an apparent aging process in others, these rods kept on increasing their resistance while in service.

As has been shown, when the resistance reaches a certain point, the discharging efficiency is greatly impaired. If a severe discharge occurs, however, it usually flashes over the surface of the rod. The normal current, following the path thus established, destroys the arrester.

In other instances the resistance increases to a value sufficient only to prevent the flow of enough normal current to operate the circuit opening device. In this event the discharge may pass through the resistance rod, but the arrester is destroyed by the continuing flow of normal current.

There are resistance rods on the market to-day, however, that entirely overcome this trouble, as after four years' service absolutely no increase of resistance is shown. These rods are composed of a combination of a special grade of carborundum, kaolin and a high percentage of metallic conducting material, properly fluxed at an extremely high degree of heat in the firing kilns.

Modern arresters are so designed that the discharge has practically a straight path to earth. They overcome many of the troubles of the older forms, due to an insufficient surface distance on the arrester base, between parts of opposite potential.

Many arrester failures are due to the use of iron boxes. An iron box offers an inductive effect to a discharge, and this effect becomes very marked as the frequency of the oscillations increases. Often the discharge jumps around the insulating bushings surrounding the leading-in wires, the normal current follows, and establishes a serious short-circuit. Wooden or asbestos lumber boxes are greatly to be preferred; the former are cheaper than iron and quite durable, while the latter have their fireproof qualities to recommend them. For car service asbestos lumber boxes should always be used, as any lightning arrester, unless properly fireproofed, may burn out and hazard valuable apparatus.

If arresters are properly designed to meet service conditions; if they are properly installed and frequently inspected to see not only that the arresters themselves are in good condition, but that the ground connections are likewise, users may reasonably expect several years' service from an equipment of the present-day product.

If tell-tale papers be put in the gaps of lightning arresters it will be a matter of considerable surprise to note the number of discharges taken. If this practice is continued for a period of two or three years, it will enable railway operators to determine where discharges most frequently occur, and at these points, arresters may be installed more frequently and better results thereby secured.

On any installation where lightning storms are at all severe, some arresters will be destroyed each year, simply because every once in a while they receive a discharge that no lightning arrester ever made would be able to withstand; but the arresters destroyed in this way have easily paid for themselves many times over. Only such a discharge as would seriously endanger the more expensive apparatus would injure some of the modern arresters now on the market.

As a sample of what has been accomplished, one of the large interurban roads in the center of the lightning belt of Indiana has shown a total loss of lightning arresters of less than 6% of the entire equipment during a period of three years, or 2% per year. This company inspects its arresters frequently, and the saving of lightning arresters due to this inspection, together with the increased protective efficiency of their arrester equipment, has more than paid for the inspection. Another company, located in practically the same territory, operating at 1,200 volts direct-current since 1906, has lost or had partially damaged in the past three years a total of but six arresters out of 225 originally installed, and during that time have lost absolutely nothing in the way of equipment. On this property frequent and careful inspections are the rule.

The foregoing statements refer throughout to lightning protection of direct-current circuits. A large part is equally pertinent in relation to alternating-current circuits. The design of alternating current lightning arresters has presented very different but quite as difficult problems as direct-current railway circuits. In the alternating-current field we have not only the so-called "external" manifestations of static to care for, but the "internal" and their resulting phenomena as well, such as those caused by "arcing grounds," switching, short circuits, etc. The characteristics of alternating current are taken advantage of very nicely in practically all modern types of alternating-current lightning arresters. The use of several air-gaps in series, where the current flow is limited to certain values by various means, results in the failure of the arc in the gaps, when the current wave passes through zero. In some forms of alternating-current arresters this action is supplemented by shunting some of the gaps with a series resistance, in others a circuit-breaker cuts off the flow of normal current, if for any reason the air-gaps fail to respond promptly.

There is no more fitting conclusion than to remark that the price of satisfactory lightning protection is proper installation and inspection. The manufacturers to-day may be said to have done very well with this problem, as is evidenced by highly satisfactory general results. But these satisfactory results are secured only when the operating companies cooperate by giving the arrester installation the proper care.

A PROJECT FOR A SHIP CANAL FOR LAKE VESsels from Cleveland southward along the Cuyahoga River to Akron, about 30 miles, has been considerably agitated in Ohio recently. Investigation of the project by the State Board of Public Works and the State Engineer, Mr. Charles E. Perkins, indicates that the canal would be enormously expensive; $25,000,000 is named as a tentative estimate. The water-supply is also thought to be insufficient for any considerable traffic, as some 20 locks would be required to overcome the difference in elevation.

WEDGE-SHAPED SEPTIC TANKS for treating sewage were mentioned incidentally, as worthy of consideration, by Mr. Alfred J. Martin, M. Inst. C. E., in a paper read on July 19, 1909, before the Health Congress at Leeds, England. Referring to the Fifth Report of the Royal Commission on Sewage Disposal Mr. Martin said:

> As regards the shape of the tanks a consensus of opinion was manifested in favor of the rectangular form. No consideration, however, appears to have been given to wedge-shaped tanks, arranged as sectors of a circle on plan, a form which would seem to have the advantages of bringing the whole capacity of the tank into use, and securing a minimum speed of flow at the outlet.

FLYWHEEL BREAKAGES are by no means so infrequent to-day as one is apt to believe. Thus, the November bulletin of the Fidelity & Casualty Co. reports, for a period of about five weeks (Sept. 9 to Oct. 14) no less than six cases of burst flywheels in the United States and Canada. The list accounts for two persons killed, several severely injured, and a large money loss.

The same bulletin lists 13 elevator breakages and 58 cases of persons otherwise killed or injured in elevator shafts. Of boiler explosions 29 are listed, including 3 steamships and 5 locomotives; besides there were 6 cases of steam pipes bursting and one crown sheet failure.

The Pollution of the Merrimack River.

For more than twenty years past the sanitary quality of the Merrimack River has been studied as has that of few other streams in the world. A summary of the earlier studies, with extensions in many particulars and conclusions based on the investigation as a whole, has been made by the Massachusetts State Board of Health, in response to the following resolution of the State legislature of 1908.

> Resolved, That the state board of health is hereby authorized and directed to investigate and report upon the sanitary condition of the bed, banks and waters of the Merrimack River, and of the streams tributary to or, adjacent thereto, in any city or town bordering upon the said river or streams. The board shall ascertain whether the condition of said river or streams or the banks thereof is injurious or dangerous to public health by reason of the entrance of sewage or of refuse from factories, or from other causes; and if they find that any circumstances injurious or dangerous to the public health exist, they shall recommend a plan or plans for their removal, and shall report the same to the next general court. [Approved May 28, 1908.]

We have quoted this resolution to show both the authority for and specific object of the investigation, and as an example of the simple and business-like way in which the Massachusetts legislature inaugurates many important investigations.

The report which resulted from the resolution was published some weeks ago in pamphlet form and will presumably appear in one of the annual reports of the State Board of Health. The report consists of brief findings of the board, signed by Mr. Henry P. Walcott, Chairman, and a detailed review by Mr. X. H. Goodnough, Chief Engineer of the Board.

Mr. Goodnough introduces his report by stating that samples of Merrimack River water have been analyzed by the board since the beginning of its examination of public water-supplies in 1887. When these analyses were begun the cities of Lawrence and Lowell were taking water from the Merrimack for domestic purposes, without purification. That practice was discontinued years ago, but Lawrence still uses the water after slow sand filtration. Otherwise, the river is not drawn upon for public water-supply, so that phase of the sanitary condition of the Merrimack "has been excluded from consideration in this report."

Mr. Goodnough next describes the river and its tributaries, and their pollution in detail. The Merrimack is an interstate stream, with 1,185 sq. mi. of its drainage area of 4,995 sq. mi. in New Hampshire. The summer flow is regulated to an unusual degree by natural and artificial storage.

The total population on the drainage area of the Merrimack was 640,000, or 128 per sq. mi., in 1900, and the population may now be taken as 740,000, or 148 per sq. mi. About one-third of the 1900 total population, or 220,000, was in New Hampshire, giving an average of 58 per sq. mi. in that State and 354 in Massachusetts. The five cities in New Hampshire with populations of more than 5,000 in 1900, were Concord, Franklin, Laconia, Manchester and Nashua, with an aggregate population of 114,315. In Massachusetts, in 1900, 16 cities and towns with above 5,000 inhabitants had a total population of 341,474. It is assumed that all the New Hampshire places in excess of 5,000 population, and it is known that all those in Massachusetts have sewerage systems. Of the 16 Massachusetts towns just named 8 have established sewage purification works [but these include none of the larger cities. —Ed.].

We may now quote from Mr. Goodnough's report, as follows:

Distribution of the Pollution Discharging Sewage into the Merrimack River.

The distribution of the population discharging sewage directly into the Merrimack River and its principal tributaries, the Pemigewasset and Winnipesaukee rivers, is shown by Table I.

From Table I. it appears that the New Hampshire towns which discharge sewage into the river are quite evenly distributed along its course, but the spaces between the towns become smaller in the lower part of its course, while the towns become larger. The greatest concentration of population along the river is between Lowell and Haverhill, a total distance, following the stream, of

TABLE I.—DIRECT SEWAGE POLLUTION OF THE MERRIMACK RIVER AND ITS TWO MAIN TRIBUTARIES.

City or town.	Distance (in miles). Below preceding station.	Distance (in miles). From mouth.	Estimated population in 1908.*
Laconia	....	121.0	9,700
Franklin	13.5	107.5	7,500
Concord	22.5	85.0	22,000
Manchester	17.5	67.5	69,000
Nashua	17.5	50.0	26,500
Lowell (Chelmsford and Dracut)	11.3	38.7	112,300
Lawrence (North Andover and Methuen)	11.2	27.5	90,800
Haverhill	10.0	17.5	42,400
Newburyport (Amesbury)	15.0	2.5	23,500
Total	....	....	403,700

*Based on increase, 1890-1900.

approximately 20 miles. Within that distance the river receives the sewage of the city of Lowell, with part of that of the adjacent towns of Dracut and Chelmsford, the sewage of the city of Lawrence and of the adjacent towns of Methuen and North Andover, and the sewage of the city of Haverhill. The aggregate population of these places at the present time is about 245,000.

Pollution from Manufacturing Wastes.

In addition to the pollution by domestic sewage, the Merrimack River is also polluted by manufacturing wastes from a large number of factories and mills along the river and its tributaries. The factory wastes which have the most serious effect in polluting the stream are those from woolen mills, paper mills and tanneries, and to a less extent from dyeing, bleaching and other processes.

From such information as it has been practicable to obtain as to the quantity of manufacturing waste discharged into the Merrimack River and its tributaries within its limits in Massachusetts, it appears that one of the most serious sources of pollution of the stream is the waste from woolen mills, especially from the process of scouring wool. The quantity of wool-scouring waste discharged into the stream annually within the limits of Massachusetts is evidently very large in proportion to its flow; and the great bulk of this objectionable waste is discharged into the river at Lawrence in the middle of that reach of the river which is most seriously polluted by sewage.

Determination of the Effect of Pollution of the Stream.

When the sewage of a city or town is discharged directly into a stream, its effect is most marked within a comparatively short distance below the point at which the discharge takes place. Farther down, the effect of the pollution, if no more is added, gradually diminishes from dilution, sedimentation and the oxidation of the organic matter by the oxygen contained in the river water, by organic growths and probably in other ways. The distance to which the effect of a given amount of pollution is noticeable depends upon many circumstances, and varies greatly in the different seasons of the year and in different years. When the quantity of sewage discharged into a stream at a given point is very small in proportion to the flow of the stream, the apparent effect may quickly disappear, and it may be impracticable to detect it even by analysis within a short distance; and the effect of even a considerable quantity may disappear, so far as ordinary tests can show, within a few miles. In cases where a stream is grossly polluted by sewage at one point of its course, the effect, so far as it is determinable by the appearance or odor of the stream, will diminish gradually if no more pollution is added, but will be traceable by analysis for a long distance beyond the point where it ceases to be noticeable by inspection. The effect of sewage pollution upon a stream may be modified very considerably by the character of the stream below—by the presence of mill-ponds or flats, by the movement of tides, and other circumstances. A very sluggish current or the presence of mill-ponds may in the earlier stages of serious pollution limit or retard the progress of the effect of the pollution down a stream by affording opportunity for sedimentation, and a longer time for decomposition, oxidation and other changes in the organic matter; but in cases of gross pollution such conditions below a sewer outlet may tend to make the effect of the pollution to some extent cumulative.

In the case of the Merrimack River, the cities and towns discharging sewage into its upper waters are located at considerable distances apart, and opportunity is afforded for the stream to recover, in part at least, from the pollution at one point before it is polluted again at the next one.

Comparative Dilution at Various Points.

In order to compare the degree of dilution of the sewage at different points in the stream, the following table has been prepared, showing the ratio of the population discharging sewage to the flow of the stream at each of the principal cities and towns along its course.

Owing to lack of information as to the pollution of the stream in New Hampshire, it is impracticable to give a fair estimate of the conditions in that State. The river at Manchester is doubtless affected somewhat by the sewage of Concord and the towns above; and at Nashua the river receives not only the pollution from that city, but is doubtless affected also by that from Concord, Manchester and the other towns on the main stream above, as well as by that from Fitchburg and Leominster on the Nashua River. The population in the principal cities and towns discharging sewage into the Merrimack and Nashua rivers at and above Nashua, including that of Nashua itself, was in 1900 in New Hampshire 114,315, and in Massachusetts (Fitchburg and Leominster) 43,923, or a total of 158,238. At the present time this population probably amounts to 180,000.

A comparison of the analyses of the water of the Merrimack River above Lowell with those of other polluted streams indicates that the pollution coming down the river to Lowell is equivalent to the sewage of a population of at least 70,000 discharging above Lowell; and that figure has been used in estimating the amount of dilution at points below, as given in Table II.

Comparison with Other Polluted Rivers.

In order to compare the conditions shown in Table II. with the conditions in other polluted rivers in Massachusetts, observations of which have been made for a considerable series of years, Table III. has been prepared on the same basis as the foregoing, including both the Merrimack River and other rivers:

Actual observations of the conditions at each of the places mentioned in the foregoing table show that all of the rivers in the last part of the table, beginning with the Manhan River at Easthampton, are now very objectionable both in appearance and odor in the drier portion of nearly every year, because of the great amount of pollution which they receive, and some of them are very offensive. The maximum amount of dilution in any of these cases is 3.4 cu. ft. per sec. per 1,000 persons discharging sewage into the stream, and there is no reason to doubt from these observations that when a stream is polluted by sewage to that extent a nuisance will surely follow. Where evidences of serious pollution are found with much higher dilutions, it is usually found that a considerable quantity of foul manufacturing waste is added to the stream; as, for example, at Webster, where the dilution of the French River is equivalent to 5.8 cu. ft. per sec. per 1,000 inhabitants, yet the stream is very dirty and has an offensive odor at times. A great quantity of wool-scouring waste is discharged into the French River both at Webster and above, which no doubt assists greatly in producing objectionable conditions. At Taunton, where the dilution is about the same as at Webster, the pollution has already had a marked effect upon the river. There is a considerable quantity of manufacturing waste discharged into the Taunton River at Taunton, and a considerable quantity of wool-scouring waste is discharged into one of its tributaries. The effect of the discharge of sewage into the Taunton River is complicated by the fact that the stream is a tidal one, and the sewage tends to accumulate during the incoming tide.

With higher dilutions than those at Taunton and Webster the effect of sewage upon the streams into which it is discharged is less marked. Unfortunately, no case is available excepting in the Merrimack River where the dilution is greater than at Webster until a dilution of 9.2 cu. ft. per sec. per 1,000 inhabitants is reached, which is found on the Ware River at Ware. The Ware River, like the French River at Webster, is polluted by a large quantity of wool-scouring waste in proportion to the flow of the stream, a portion of which is, however, discharged into the river at a distance of several miles above Ware. Next to Ware the greatest dilution at any of the places where sewage is discharged is found at Westfield, where it amounts to 10.2 cu. ft. per sec. per 1,000 persons. In this case there is comparatively little manufacturing waste of an objectionable character discharged into the stream, either at Westfield or above; and, while the effect of the sewage discharged into the Ware River at Ware is clearly noticeable for a considerable distance below the sewer outlet there, the effect produced by the discharge of sewage at Westfield is as yet comparatively slight, except in the immediate neighborhood of the sewer outlet.

TABLE II.—DRAINAGE AREAS, POPULATION CONTRIBUTING SEWAGE AND RELATIVE POLLUTION AT VARIOUS POINTS ON THE MERRIMACK RIVER.

Point considered.	Drainage area (sq. mi.).	Estimated dry-weather flow* (cu. ft. per sec.).	Estimated population discharging sewage into stream.†	Flow per 1,000 persons discharging sewage (cu. ft. per sec.).
Above Lowell	4,127	2,022	70,000	29.0
Below Lowell	4,636	2,318	182,300	12.7
Below Lawrence	4,840	2,369	273,100	8.7
Below Haverhill	4,899	2,384	315,500	7.6

*.50-cu. ft. per sec. per sq. mi. above Lawrence; .25-cu. ft. per sec. per sq. mi. below Lawrence.
†Including places above.

In the case of the Merrimack River, if Lowell, Lawrence and Haverhill and the towns adjacent to those cities are to be considered as one city, and the flow at Haverhill is taken to represent the dilution of the sewage, the ratio of flow to the population will be 9.7 cu. ft. per sec. per 1,000 persons discharging sewage into the stream. On the Merrimack River an enormous quantity of wool is scoured, chiefly in establishments located in Lawrence and adjacent towns; and, while no definite estimate of the actual quantity of wool scoured on the stream can be given, it is probable that the proportion of wool scoured to the flow of the stream on the Merrimack River at Lawrence and above is not very different from that in the case of the Ware River, and may possibly be as great as on the French River. The quantity of sewage discharged into the Merrimack River from the cities and towns specified, however, is much less in proportion to the flow of the stream than it is in the case of the French River, and is not very different from the amount discharged into the Ware River at Ware or the Westfield River at Westfield. Considering, however, the amount of manufacturing waste discharged into these rivers, it would be expected that the condition of the Merrimack River below Haverhill would more nearly resemble that of the Ware River below Ware than any of the others in Table III.

Further and more definite information on this point is furnished by a consideration of the chemical analyses.

Condition of the Merrimack River at Various Points, as Shown by the Results of Chemical Analyses.

The examinations of the Merrimack River, as already stated, were begun in 1887, and samples of water have been collected monthly for chemical analysis throughout the year from that time to the present at two points upon the stream, viz., above the dam at Lowell and above the dam at Lawrence. [We omit, for lack of space, some interesting dry-weather flow figures for the Merrimack. —Ed.]

Taking up the first long series of analyses above the city of Lowell, an examination of the results shows that there was very little change in the quantity of free ammonia in the river water during the first few years of the observations; but since the year 1895 the free ammonia has increased steadily from about .0025 of a part per 100,000, the average of the earlier years, to about .0125 of a part per 100,000, the average of the past three years.

TABLE III.—COMPARATIVE POLLUTION OF MERRIMACK AND OTHER MASSACHUSETTS RIVERS.

Name of stream.	Drainage, sq. mi.	Estimated dry-weather flow, cu. ft. per sec.	Population discharging sewage at point referred to, estimated, 1908.	Flow per 1,000 persons discharging sewage, cu. ft. per sec.
Connecticut River below Northampton and Easthampton	8,539	3,500	25,100	139.4
Quaboag River at Palmer	213	73	1,280	57.0
Chicopee River at Indian Orchard	696	200	3,800	85.0
Merrimack River above Lowell	4,127	2,022	70,000	29.0
Connecticut River below Springfield, including cities and towns within 30 miles above	9,922	3,970	172,000	23.1
Millers River at Orange, including Athol	322	116	8,350	13.9
Merrimack River below Lowell	4,636	2,318	182,300	12.7
Westfield River at Westfield	455	123	12,000	10.2
Ware River at Ware	192	60	6,500	9.2
Merrimack River below Lawrence	4,840	2,369	273,100	8.7
Merrimack River below Haverhill	4,899	2,384	315,500	7.6
French River at Webster	93	50	8,600	5.8
Taunton River at Taunton	351	158	27,500	5.7
Nemasket River at Middleborough	59	15	3,200	4.7
Fort River at Amherst	41	10	2,200	4.5
Manhan River at Easthampton	70	18	5,300	3.4
Green River at Greenfield	90	23	7,600	3.0
Ten Mile River at Attleborough	21	8	3,700	2.2
Hoosick River at Williamstown, including North Adams	177	46	28,200	1.6
Charles River at Milford	11	3	2,300	1.3
Hoosick River at North Adams	119	32	27,100	1.2
North branch Nashua River below Leominster, including Fitchburg	95	38	44,000	0.9
North branch Nashua River at Fitchburg	62	25	33,800	0.7
Mill River at Northampton	55	14	19,000	0.7
Monoosnock Brook at Leominster	11	5	9,150	0.5

The albuminoid ammonia has increased from about .0150 of a part per 100,000 in the earlier years to about .0200 of a part at the present time. This increase is especially marked in the amount of albuminoid ammonia in suspension. A similar increase is noted in the oxygen consumed and in the chlorine, while there has been at the same time a gradual reduction in the quantity of nitrates present.

The cause of this increasing pollution of the river is no doubt due in part to an increase in the polluting matter discharged into the stream in New Hampshire, but also without doubt to the great increase in the pollution of the Nashua River, chiefly by the sewage and manufacturing wastes in the city of Fitchburg and other places in Massachusetts.

The results of the analyses of samples of water collected from the river above Lawrence, which include of course the effect of the sewage discharged at Lowell, show, when compared with the analyses above Lowell, a marked increase in the quantity of organic matter in the river, due to the addition of the sewage and manufacturing waste of Lowell to the pollution already in the river as it reaches Lowell. The analyses of the water above Lawrence, however, show that the effect of the pollution discharged into the river at Lowell has become greater in recent years than formerly. Comparing the analyses above Lawrence with those above Haverhill, where a considerable number of samples has been collected in the last eight or nine years, the results show a still further decided increase in the quantity of organic matter present in the river water. This increase is comparatively slight in the amount of free ammonia, but is especially marked in the amount of suspended albuminoid ammonia present in the river water above Haverhill.

In order to compare the conditions from point to point along the river in different years, another series of diagrams* has been prepared, comparing the results of the analyses in the years 1903, 1904, 1906 and 1908, or such of them as are available, at points above Nashua, Lowell, Lawrence and Haverhill, and also at a point below Haverhill, where a considerable number of samples has been collected in each of the years mentioned. The diagrams show a comparison of results of the analyses from June to November, inclusive, in each of the years mentioned.

By referring to the table [omitted here—Ed.] it will be seen that the year 1903 must be classed as a wet season, the flow being greater than the average and about twice as great as the ordinary dry-weather flow. The year 1904 would be classed as a dry season, the flow being about 50% greater than in the driest year since 1887. The year 1906 was a year of average flow, while the year 1908 was the driest of those included in the table.

In the wet year 1903 the analyses show that the quantity of albuminoid ammonia in suspension above Lowell was a little less than at a point above Nashua, but there was a regular and marked increase at each of the other points going down stream, and the amount present in the water below Haverhill was nearly twice as great as in the water above Lowell. A similar marked increase between the point above Lowell and the point below Haverhill is shown in the other years mentioned.

In 1904, when the flow was considerably less than in 1903, the effect of pollution in the water is more marked. In 1906, however, though the quantity of water flowing in the stream was considerably greater than in 1904, nevertheless there was an increase in the total quantity of albuminoid ammonia present in the water at all but one point. The suspended albuminoid ammonia, however, was on the whole less in 1906 than in the years 1903 or 1904. In 1908, the driest year of those under consideration, the pollution is more marked than in either of the others. The other determinations show a similar result. There is a constant increase in the quantity of pollution in the river water going down stream, the increase being most marked in the vicinity of Haverhill, where the quantity of organic matter in the river water as shown by the albuminoid ammonia is on the average in these years nearly twice as great as is found in the river above Lowell.

Comparison of the Analyses of the Water of the Merrimack River with Those of Other Polluted Streams.

In order to compare the condition of the Merrimack River with other polluted streams in the state, Table IV. has been prepared showing the quantity of albuminoid ammonia, free ammonia, chlorine and suspended albuminoid ammonia in the waters of several polluted rivers in the state, on some of which the population discharging sewage is greater and on others much less than in the case of the Merrimack. For convenience this table has been arranged in the order of the average quantity of albuminoid ammonia present in the years 1903, 1904, 1906 and 1908, and the results of the analyses of the Merrimack River water have been included at points above Lowell, Lawrence and Haverhill, and a point below Haverhill.

[*The diagrams were not published in the report.—Ed.]

TABLE IV.—AVERAGE CHEMICAL ANALYSES FOR 1903, 1904, 1906 AND 1908 OF WATER FROM VARIOUS RIVERS IN MASSACHUSETTS AS COMPARED WITH THE MERRIMACK.

River.	Location.	Parts per 100,000. Total albuminoid ammonia.	Free ammonia.	Chlorine.	Suspended albuminoid ammonia.
Nashua, north branch	Below Monoosnock Brook	.0652	.2874	1.20	.0261
Ten Mile	Below Attleborough	.0575	.1021	1.10	.0238
Sudbury	Below Saxonville	.0374	.0223	.78	.0214
Charles	Below Milford	.0538	.2451	1.56	.0188
Charles	Below Bellingham Junction	.0494	.0121	1.25	.0159
Nashua, north branch	At North Leominster	.0476	.1669	1.02	.0166
Hoosick	Below North Adams	.0430	.0306	.50	.0201
French	Below Webster	.0411	.0116	.50	.0142
Ware	Below Ware	.0391	.0127	.30	.0108
Assabet	Below Hudson	.0358	.0202	1.10	.0076
Merrimack	Below Haverhill	.0349	.0294	.49	.0123
Hoosick	At Williamstown	.0346	.0481	.44	.0149
Merrimack	Above Haverhill	.0331	.0233	.46	.0107
Taunton	Below Taunton	.0313	.0567	1.07	.0049
Nashua, north branch	Above Lancaster	.0299	.0717	.84	.0058
Millers	Below Orange	.0269	.0107	.27	.0047
Blackstone	At Uxbridge	.0260	.2508	2.25	.0053
Merrimack	Above Lawrence	.0260	.0211	.40	.0073
Connecticut	Below Springfield	.0204	.0123	.27	.0054
Merrimack	Above Lowell	.0190	.0090	.27	.0041
Westfield	Below Westfield	.0150	.0110	.19	.0031

[We omit a series of tables showing the results of each determination at each place, arranged in order from the highest to the lowest.—Ed.]

From these tables it will be seen that the Merrimack River at the time it reaches Lowell is a considerably polluted stream. The degree of pollution, as shown by the albuminoid ammonia, is about the same as that of the Westfield River below Westfield, and somewhat less than that of the Connecticut River below Springfield. Below Lowell, after receiving the sewage and manufacturing wastes of that city, the river becomes considerably more polluted than the Connecticut River below Springfield. Below Haverhill, after receiving the sewage of Lawrence, Methuen, North Andover and Haverhill, the analyses indicate that the condition of the river is similar to that of some of the more seriously polluted rivers of the state. Comparisons with the Taunton River and Millers River are not very reliable, since a portion of the albuminoid ammonia in those streams may be due to the organic matter taken up from the extensive swamps on their watersheds. A small part of the increased albuminoid ammonia in the Merrimack River above Lawrence and at points below may be due to organic matter of similar origin brought in by the Concord River and smaller streams.

It will be noted from the tables that the quantity of albuminoid ammonia in the river water below Haverhill is as yet less than in the Ware or French rivers below Ware and Webster, respectively, while the quantity of free ammonia, on the other hand, in the Merrimack River water is considerably greater than at Ware or Webster. The quantity of albuminoid ammonia in suspension is not very different from the amount found in the Ware and French rivers at the points indicated.

The quantity of albuminoid ammonia in a polluted stream is probably the most reliable index available of the pollution of the stream; but it is important to take the other determinations into account, else in this case the standing of the Blackstone River at Uxbridge, the Nashua River above Lancaster and the Hoosick River at Williamstown would be better than the condition of those streams warrants, as a simple inspection and a comparison of the other determinations will show.

Considering all the results presented in the foregoing tables and the actual observations of the various streams, it is reasonable to conclude that the condition of the water of the Merrimack River at Haverhill is better than that of the Ware River below Ware, the French River below Webster, the Taunton River below Taunton or the Assabet River below Hudson. It is much more polluted than the Westfield River below Westfield or the Connecticut River below Springfield.

Condition of the Bed and Banks of the Merrimack River.

The bottom of the Merrimack River is usually exposed in the drier part of the year below the dams at Lowell and Lawrence, and considerable areas of the banks all along the river are uncovered at times of low flow. The exposed bed of the river in the cities of Lowell and Lawrence is for the most part ledge or is covered with boulders and stones of various sizes, and, except where sewage is discharged upon it, is clean and unobjectionable. Elsewhere the banks and bed exposed in the drier portion of the year are usually covered with very fine sand or river silt, with stretches of gravel, hardpan or ledge in places.

The river is fairly clean in appearance above Lowell, but below Lowell it contains considerable floating material and suspended matter, while below Lawrence the surface is often covered for a long distance with froth, scum and oily and greasy matters, which are especially noticeable in the summer season. An examination of the banks shows that the oily and greasy matters discharged into the stream, together with the floating scum, collect to some extent on the banks; and as the water recedes, especially in the reaches below Lawrence, the bottom is covered in places with a thin, greasy film, and the river in this region, especially along the southerly bank, has a noticeably disagreeable odor at times in summer. Elsewhere the river has not been found to be offensive between the cities.

The most objectionable conditions found along the bed and banks of the river at the present time are those caused by the sewer outlets of the various cities. [Details of sewer-outlet conditions are here omitted.—Ed.]

Condition of the Tributaries of the Merrimack River.

In considering the pollution of the tributaries of the Merrimack River reference has already been made to certain of these streams which are badly polluted by sewage in the cities of Lowell, Lawrence and Haverhill and adjacent towns. The condition of these tributaries where the pollution is very serious, such as in the case of the Spicket River in Lawrence, might be greatly improved without serious difficulty by removing the sewage and other polluting matters from the present outlets and discharging them directly into the Merrimack River. There are polluted tributaries, however, which receive their pollution at long distances from the Merrimack. Chief among these are the Nashua River, the north branch of which, is grossly polluted by sewage and manufacturing wastes, chiefly from the city of Fitchburg and the town of Leominster. This river is offensive for a long distance below the city of Fitchburg, and the condition of its water is very objectionable, as shown by chemical analysis, for many miles.

During the drier portion of the year 1908 samples of water were collected monthly from the river at a point below Pepperell, 3 miles from the state line and 10 miles from the mouth of the river at Nashua. The results of these analyses show that the river was very badly polluted at that point, and its objectionable condition no doubt has a considerable influence in the pollution of the Merrimack River above Lowell. If the sewage and manufacturing waste now discharged into the north branch of the Nashua River should be removed from that stream and purified, the result would be a great improvement in the condition of the Nashua River lower down, and would no doubt have a considerable influence in improving the condition of the Merrimack River above Lowell, or at least in arresting its deterioration.

The Assabet River, as already stated, is very badly polluted at several points along its course, and the Sudbury River also is considerably polluted by manufacturing waste discharged into the stream at Saxonville. The water of these streams after uniting to form the Concord River at Concord is diluted by clean water from the watershed below, and again polluted somewhat by manufacturing wastes discharged into the stream at North Billerica. The stream is not, however, very seriously polluted at the point where it enters the city of Lowell. The condition of the Assabet River, however, is such as to require that some action be taken toward effecting the removal of the pollution from the stream, and when this is done there should be a considerable improvement in the character of the water of the Concord River.

The Merrimack River below Haverhill receives comparatively little pollution until near its mouth, where it receives a part of the sewage of the town of Amesbury and all of that of the city of Newburyport. The sewage of these places, however, does not have a marked effect on the appearance of the stream, and no analyses are available to determine its exact condition in that region.

Summary.

The Merrimack River at the present time is polluted by the sewage of a population of about 400,000 living in the cities and towns along its course, but concentrated chiefly in the 20 miles between Lowell and Haverhill, within which distance the population discharging sewage into the stream is about 245,000.

In addition to the large amount of sewage which the river now receives, it is polluted by a great quantity of manufacturing wastes of kinds which contain large quan-

tities of objectionable organic matter. Chief among these wastes are those from wool scouring, large quantities of which are discharged into the river in and about the city of Lawrence. The river also receives a large quantity of foul waste from the washing of cloth, spent dyes, etc., and from paper mills, tanneries and other establishments.

The combined effect of the pollution does not as yet appear to make the river water offensive at any point along the course of the stream excepting in the immediate neighborhood of some of the large sewer outlets and near the southerly bank just below Lawrence. The analyses of the river water, however, show a decided increase in the pollution of the stream within the last few years; and, while the river can doubtless continue to remove the amount of pollution it now receives, there is no doubt that, if the cities along the stream continue to grow and the amount of manufacturing continues to increase, the time will come when the river water will become so polluted as to be offensive to those living along its banks.

* * * * *

The Merrimack River, if allowed to become grossly polluted, is capable of very injurious effect upon the public health in the densely populated region through which it flows in Massachusetts; and it is important that it shall not be subjected to a much greater load of pollution than it is carrying at the present time, and especially that the pollution shall not be allowed to become serious before effective measures for removing the remediable pollution have been taken.

Considering the extent to which the river is now polluted, it is very important that in future both the river and its principal tributaries should be examined from time to time and their waters analyzed at several stations and at frequent intervals, and that careful records of such observations be kept, to make it practicable to determine the changes taking place in the condition of the stream. It is also important that the sources of pollution be determined, including the amount and character of the manufacturing waste discharged into the stream or its tributaries at points within the state, and that in future the admission of sewage or other polluting matters into the stream be subject to supervision and unnecessary pollution prevented.

While this river cannot reasonably be placed under the sanitary regulations necessary for streams used as sources of water supply, there appears to be no good reason why it should any longer be made an exception to the sanitary laws controlling the other rivers of the state, so far as its pollution may affect the health of persons living upon its banks.

The report transmitted by the board itself is in part a repetition, in epitome, of Mr. Goodnough's report. The following paragraphs are given as representing the official opinion of the board:

At present this stream of water is not in a condition to be injurious to the public health, and by proper regulation it may be kept many years, perhaps generations, free from danger.

There are, however, many localities in each of these cities, near the outlet of sewers, where the stream is locally polluted, the sewage not being disseminated through the stream; and where the bed and banks at night and on Sundays, when the mills are not running, and at low tide near the lower city, are exposed, coated with the refuse of sewage and of some manufacturing wastes. At these places the conditions are injurious to the health of those living or working near.

These conditions may be obviated in general by extending the sewer by an iron pipe, smaller than the sewer, but large enough to convey the ordinary sewage to beyond the edge of the stream at the lowest stage and discharging under water, so that a clean stream of water may continually flow between the shore and the outlet. In this way the sewage becomes diluted by the water into which it is discharged, and the shore is kept clean.

Of the manufacturing wastes, the most obvious and the one that causes the most complaint upon this river is that resulting from the scouring of wool. This process of washing and discharging the effluent containing large quantities of grease into the river results in a grease-covered shore and bed for a long distance down stream. The grease associates with and holds other objectionable matter, and, while we cannot say that it has up to this time been injurious or dangerous to the public health, it has become very disagreeable. The boatmen at Haverhill complain of the black grease adhering to their boats. It is at present a very disagreeable addition to the river, and may become injurious to the public health.

In other countries, and to some extent in this, the grease, which is the objectionable element in the effluent, is removed and made into valuable articles of commerce.

It would probably be no great hardship if the scourers of wool were required to keep the grease out of the river. If this were done, the appearance of the river would be very much improved and the ground for much of the complaint in regard to its present condition removed.

The pollution entering this river from beyond the state renders it impracticable to include it with those rivers used for water supplies; but the local nuisances and the increasing pollution require that more complete regulation be applied to this river, and to this end the Board recommends that Sec. 123 of Chapter 75 of the Revised Laws be modified to read as follows:

Sec. 123. The provisions of the five preceding sections and of so much of sections 112 to 117, inclusive, as refer to domestic water supplies shall not apply to the Merrimack or Connecticut rivers, nor to so much of the Concord River as lies within the limits of the city of Lowell, nor to springs, streams, ponds or water courses over which the Metropolitan Water Board has control.

Settlement of an Old Pile Foundation Causes Sudden Alarm.

A spectacular proceeding of the past week, the evacuation of the New York County Criminal Court building, aroused general wonder among those concerned with building operations. The cracking of this building was mentioned in a note in our last issue. On Nov. 3 the city's Superintendent of Buildings decided that the structure was dangerous, and ordered the police to clear the building. Since then a line of policemen has kept all comers out of the building and blocked traffic in the four adjoining streets. The proceeding surprised and alarmed the local public very greatly. Incidentally it disarranged the whole criminal trial machinery of the county and indeed paralyzed it for several days. Elsewhere the impression was produced that something of exceptional gravity must have come to pass, in order to warrant the unprecedented action of the authorities. The following general statement of facts will indicate how far these impressions are correct.

The Criminal Court building is a four-story stone structure about 200 ft. square, lying between Center St. and Lafayette St. (on the east and west), and Franklin St. and White St. (on south and north). Its floors are terra-cotta arches between steel beams which rest on stone and brick exterior and interior walls. In ground plan, wide central corridors extend through the building in both directions, and cut it up into four large blocks or towers occupying the four corners. The exterior walls are recessed along the middle part of each face, at the ends of the corridors, so that the arrangement of space is indicated externally. It is important to note that these recessed portions of the outside walls are thinner than the remainder.

The site is on the edge of the former Collect pond, filled in during the first year of the 19th century. The westerly half of the building is on a sandy subsoil, while the easterly half is on the marsh or fill soil. Rock is quite deep below the surface, probably nearly 100 ft. To make a foundation, the site was thoroughly piled; the piles were not capped by a continuous sheet of concrete. The plans recorded in the Bureau of Buildings do not give detailed information about the pile work.

The building was erected between 1890 and 1894. Defects due to settlement, causing cracks to appear, were noted early. They became somewhat more marked, perhaps, after 1900, when work was begun along Lafayette St., on the west side of the building, to construct the Rapid Transit Subway, which required excavating to a depth of some 20 ft. on the full width of the street. The continued progress of settlement made necessary frequent patching of plasterwork, etc.

A few years ago, conditions were about as follows: A line or zone of vertical cracks ran north and south through the building, about centrally, showing as cracks in the thin middle part of the exterior walls and opening up floor and wall cracks in the interior. The floor cracks did not affect the integrity of the arches, these being well tied by the steel, but centered at the edge of floor sections where the channel-iron at the side of an arch lay along the wall.

The cracking was traced to a settling of the easterly half of the building. The westerly half was fairly level, and, assuming it undisturbed, served as a reference level for the east half. The latter was four or five inches low at its eastern edge, along Center St. This evidently implied a tilting of the east half toward Center St., which would open cracks in the weak central part of the northerly and southerly walls, just as existed. Correspondingly, the east wall was out of plumb, leaning several inches eastward. The west wall leaned but slightly in the same direction.

Two years ago, after long-continued complaint, an investigation of the condition of the building was started, and the building has been under observation since. A report was rendered a few weeks ago, but is still in the hands of the Borough President and has not been made public. The examiners were Mr. R. P. Miller, M. Am. Soc. C. E. (Consulting Engineer) and Mr. D. E. Moran, M. Am. Soc. C. E. (The Foundation Co.). It is surmised that their report condemns the foundation as too weak, and discusses the question of underpinning the building. At any rate, officials of the Borough President's office have been quoted as saying that reconstructing the foundations is necessary, but will cost $200,000 to $300,000.

After this investigation was started, work was begun on the excavation for a subway line in Center St., east of the building, to be part of the Bridge Loop Subway. During this excavation work, the periodical troubles from settlement became rather more marked. More and larger cracks appeared. In one case an 8-in. water main embedded in one of the floors was broken by the pulling-apart movement, and much damage done by water. It is said that the electric light wiring as well as the piping has been deranged frequently. Falling bits of plaster, etc., have contributed largely to impressing the occupants of the building with a fear that it was in dangerous condition. However, the engineering force of the Public Service Commission directing the subway work, found that the additional movements which occurred during this period were relatively small.

The present state of the structure is roughly as has been described, i. e., a pronounced line of cracking extends north and south through the building, near the center, where the walls are thinnest and most cut up by openings. In the exterior walls fronting on Franklin and White Sts. this appears in a number of vertical cracks, one or two being continuous from about the second floor level to the roof. The largest is over an inch wide near its upper end, and extends clear through the wall and plaster. The interior cracking corresponds, but is more scattered.

The progress of the cracking has been rather more marked in the past week or two than before. Unverified reports have it that strips of paper pasted over several cracks in the interior of the building were torn within two days, indicating steady and pronounced continuance of the settlement. Broadly speaking, however, present conditions are not different from those existing for a long time past; nothing threatens early failure, and the only direct danger seems to lie in the chance that a piece may break out of a window sill or arch and fall on passersby in the street. On the south face of the building, one window arch which is cut in two by the widest crack on that side has for some time past been ornamented by struts and lagging. The suggestion that other openings in the zone of cracking be protected similarly does not appear to have been entertained by the building authorities.

The question whether plain settlement or deterioration of the piles has occurred is to be decided by test pits sunk at the corners of the building. The piles project above the level of the subway floors, and during the excavation period at least they have been partly in dry ground through lowering of the water level. What evidence is to hand at present argues against rotting of the piles and seems to indicate ordinary progressive settlement. It is to be noted in this connection that the passage of trains in the Lafayette St. subway causes perceptible vibration on the upper floors of the building.

Since the foregoing was written, a further report on the condition of the building was made, and this has been published. A committee of three engineers in the city employ was appointed by the Borough President after the building had been forcibly evacuated, to determine whether or not it really is unsafe, and what needs to be done. Referring to the superstructure alone, they report that long-continued settlement of the foundation along the east side has disturbed the structure seriously, so that there is danger of pieces of material falling at the cracks.

They recommend immediate protection work as follows: Shoring the openings in the north and south court walls; shoring the exterior openings in the north and south walls which show displacement of material or cracks, at the same time removing loose material and replacing with temporary work to make the walls weather-tight. Then the building can be occupied again, and its elevators and electrical plant put into service, but the gas pipe should be blanked off outside the building wall.

For permanent repair they recommend: Regular weekly inspection and observation for at least a year, to determine the influence of nearby excavation work and the operation of the subway traffic. If these observations indicate the need of a solid foundation, the building should then be underpinned, to solid substratum, and lastly the defects in the superstructure repaired.

This committee also reassures the authorities by stating that there is no danger in resuming traffic on the four bounding streets. But by the time the report was made these four streets, including one street-car line, had already been closed for five days!

A Light Reinforced-Concrete Wharf Construction, Madras Harbor, India.

In the present shallow basin in the harbor of Madras, India, there is a depth of only from 8 to 13 ft., but it is expected that in future a greater depth will have to be dredged. However, this possibility is not at all imminent and meanwhile some provision has to be made for wharfing facilities as well as to hold back the banks, which have a tendency to cave. For this purpose a light reinforced-concrete retaining wall and wharf has been designed and erected, somewhat similar to that in use at Baltimore harbor and described in Engineering News, Oct. 1, 1908, p. 364. The Madras system is the subject of an article by Mr. F. J. E. Spring, the Engineer-Chairman of the Madras Port Trust, in the "Indian and Eastern Engineer" for August, 1909, and from that article we have abstracted the following account:

The construction (Fig. 1) comprises reinforced-concrete piles driven 8 ft. apart to a depth of 8 ft. below bottom and tied back to an anchor by means of 30-lb. old rails completely encased in concrete. Back of these piles are sunk reinforced-concrete slabs to a point below river bottom, these slabs acting as the retaining wall to hold back the earth. The tops of the piles are joined together by an arch construction topped by a coping of old rails. Back from this coping the earth of the bank slopes to form the wharf, for while the main object of the structure is to serve as a revetment, where necessary this bank can well be utilized for a quay.

The piles are reinforced with four 1-in. rods. They are made on shore and jetted into place two or three weeks after manufacture. Near their upper end there is a bolt hole through which the old rail ties are bolted. These ties are placed as low in the ground as is possible and are hooped at their rear end around a bowl-shaped cast-iron "pot-sleeper" such as are used on foreign railways. The whole tie and anchor is then encased in concrete. The slabs are shown in Fig. 2. They are in two parts, cast on the ground, and are jetted into place with a rake-shaped set of pipes. With a span of 6.75 ft. a test load of 1,415 lbs. per sq. ft. caused no permanent deflection to one of these slabs, and this is about four times what one is called upon to resist. A 1:2:4 concrete was used for all the work.

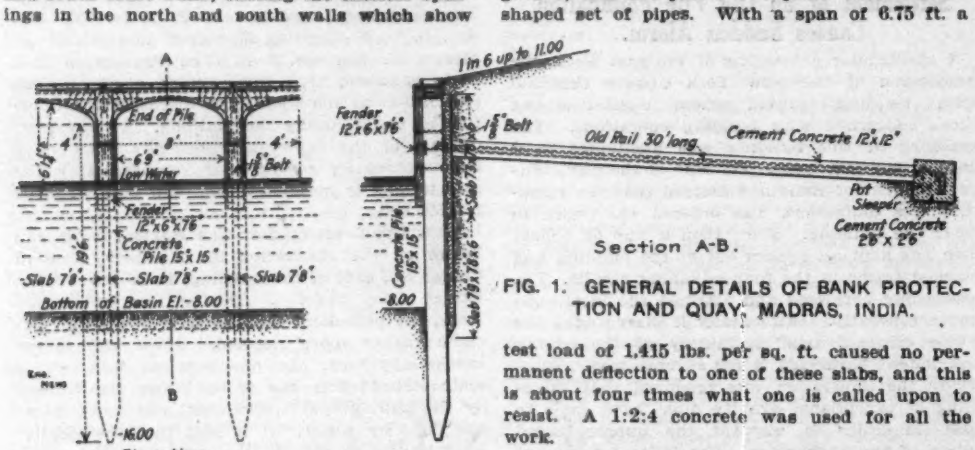


FIG. 1. GENERAL DETAILS OF BANK PROTECTION AND QUAY, MADRAS, INDIA.

This construction is very cheap, and has the advantage of being easily removed if future deepening is required. Meanwhile it effectively is serving the intended purpose.

Notes on the 1909 Conference of the International Geodetic Association.

By JOHN F. HAYFORD,* M. Am. Soc. C. E.

The sixteenth General Conference of the International Geodetic Association was held at London and Cambridge, England, Sept. 21-29, 1909. Eighteen nations, including all of the great powers, were represented by 64 delegates. Among the delegates were Dr. F. R. Helmert, of Germany, the greatest of living geodesists, H. Poincare, of France, and Sir George Darwin, of England, well known for their work in mathematics and physics, Sir David Gill, the English astronomer, and Col. Burrard, Superintendent of the Trigonometric Surveys of India. The two delegates from the United States were Mr. O. H. Tittmann, Superintendent of the Coast and Geodetic Survey, and the writer.

A formal meeting, about three hours long, for the reading of papers and reports of progress was held on each of seven days. Many of the papers and reports were presented in outline only, by merely calling attention to the principal points presented, printed copies being placed before the delegates at the time of presentation. Even under these conditions the seven-day program was crowded. In a single article of reasonable length it is not possible to summarize all of the reports and papers presented and to preserve their relative importance in the statement. The writer has therefore endeavored merely to select and present a few of the matters which are believed to be of most interest to American engineers. In doing so, more prominence than is warranted by their relative importance has been given to geodetic operations in the United States.

Among the social functions which served to promote good fellowship and informal discussion among the delegates were two banquets, two formal receptions, excursions from London to Windsor Castle, to the Greenwich Observatory and the Royal Naval Academy, and to the National Physical Laboratory; and from Cambridge to the Cambridge Observatory and the works of the Cambridge Scientific Instrument Co.

Col. Robert Bourgeois in a formal report on measurements of primary bases in all countries during the past three years called attention to the very rapid progress which has been made in substituting for the base bars 4 or 5 meters long formerly in use, steel or invar wires from 25 to 50 or even 100 meters long. The result of the change has been to greatly increase the rapidity and reduce the cost of measuring bases, without lowering the grade of accuracy. He then presented evidence from recent base measurements to show that frequently the larger uncertainties in the final adopted length of a base which has been measured with wires arise from changes in the lengths of the wires between the two standardizations, one before being used on the base and the other afterward. When such a change occurs it is impossible to tell with certainty whether it took place before, during or after the base measurement. Accordingly, the length of the particular wire at the time of the base measurement is uncertain to the extent of a part or even the whole of the observed change.

The reading of this report, incidentally, started a discussion of the relative merits of wires and tapes for primary base measurement. In the United States it has been the uniform practice to use tapes having a width much greater than their thickness, rather than wires. The delegates from the United States called attention to the abundant evidence contained in the literature of base measurement that in general, tapes change in length between the standardizations much less than wires have been found to change.

Although this claim that tapes are superior to wires in this respect was based entirely on recorded experience, attention was called also to two mechanical reasons why tapes should be expected to be more stable as to length under field conditions than wires. First, with a given area of cross section, necessary to withstand the applied tension safely, the thickness of the tape in the direction of the bending to which it is subjected during reeling and unreeling is much less than that of a wire of the same area of cross section. Hence in the tape the excess of tension in the outer fiber during reeling, over the mean tension, tends to be much less than the corresponding excess in the wire. The same principle also operates in favor of the tape during the other bendings to which it is subjected during field operations. Second, when a wire is reeled up, as it must frequently be during field operations, it is necessarily subjected to torsion about its axis. One may obtain clear evidence of this by attempting to prevent the end of a wire from twisting when the wire is being reeled. The effect of such torsion must be to produce minor changes in length. Tapes are free from such torsion during reeling.

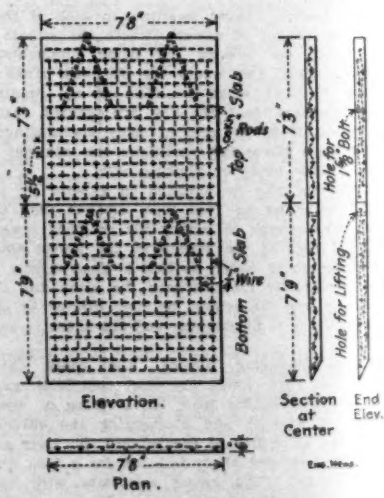


Fig. 2. Details of Slabs.

This report by Col. Bourgeois and the resulting discussion furnish an excellent illustration of the manner in which a formal chronicle of experience in a given line, if carefully prepared without bias, may lead directly to better practice.

At the International Bureau of Weights and Measures near Paris, extensive investigations of

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steel and invar wires have been made during recent years, but little has been done with tapes. Near the close of the Conference Dr. Förster, the head of the International Bureau, stated that the investigations in detail would now be extended to include tapes.

The reports show that invar has been substituted successfully for steel in base wire and tapes in many cases, and will probably supersede steel in a few years. Invar is an alloy of steel and nickel, having a very low coefficient of thermal expansion (about 1/28 that of steel, in the invar tapes used in the Coast and Geodetic Survey). The use of invar tapes or invar wires, therefore, reduces greatly the troublesome errors due to uncertainty as to the actual temperature of the tape during measurements.

The United States has an opportunity to play a strong part among the nations in geodesy since, in geodetic investigations, the accuracy of the results increases very rapidly as the continuous area covered by geodetic surveys on a uniform basis is extended, and the United States comprises a continuous area comparable in size to all of Europe. In a formal report presented by the American delegates, it was noted that the continuous triangulation available on one basis in the United States now extends into 41 of the 48 states and territories and reaches from the Atlantic to the Pacific and from Mexico to Canada. In utilizing this triangulation and the accompanying astronomic observations for determining the figure and size of the earth, new methods furnishing increased accuracy have been introduced in the United States. The computed value of the equatorial radius of the earth, based on measurements in the United States alone, is 6,378,388 meters. Its probable error in the technical sense is 18 meters. Thus it is an even chance that the computed value is within 18 meters of the truth. The reciprocal of the flattening of the earth is found to be 297.0, with a probable error of ± 0.5. These values are believed to be more accurate than any hitherto derived, even by combining the observations available in various countries. According to this computation the earth is slightly larger than it is represented to be by the Clarke or Bessel values ordinarily accepted, and the flattening is intermediate between the Clarke and the Bessel values.

One of the most important features of the new method of computation used in the United States is the definite recognition of the theory of isostasy in the computation. Let all material forming a part of the earth and lying above sea level be considered a surface excess. Then, according to the theory of isostasy, every surface excess is compensated by a defect of density in the material directly below it, the defect of density being understood to extend to a considerable depth and to be of such an amount as to compensate exactly for the excess. Under these conditions at the depth to which the compensation extends the material within the earth is in an isostatic condition. That is, the pressures are the same in all directions at any given point, as in a liquid. According to this theory, the average density of the earth's crust under a mountain, or a high plateau is less than under a plain lying at about sea level, and on the other hand, the average density under the deep parts of the ocean is considerably greater.

The evidence from geodetic observations in the United States is convincing that the theory of isostasy is true. The triangulation and astronomic observations in the United States used in determining the figure and size of the earth also serve to fix the depth to which the compensation extends at 122 kilometers (75 miles). During the Conference Dr. Helmert stated the nature of an investigation recently made by him before he had any information as to the recent computations being made in the United States. He based his computation entirely upon European observations and found a value for the depth of compensation differing by only two kilometers from that stated above. Such a close agreement between two investigations made independently by different men, and based upon observations in different countries indicates that the depth of compensation is now known with considerable accuracy.

The United States delegates presented another paper showing that observations of the intensity of gravity at 56 stations in the United States and 16 foreign stations also indicate that the condition called isostasy exists, and that the depth of compensation is approximately that stated above.

At the next previous Conference of the Association, in 1906, the word isostasy and accompanying phrases were seldom heard, except from the United States delegates. At the Conference of 1909 it was evident that the theory of isostasy had been accepted by many as proved, and that many different men in various countries were studying the modifications which must accordingly be made in geodetic methods.

Dr. O. Hecker, of Potsdam, Germany, the only man who has yet succeeded in determining the intensity of gravity on a vessel at sea with sufficient accuracy to make the result valuable, presented a paper showing that special investigations are being made with a view to improving the method. He observes the pressure of the atmosphere with mercurial barometers and at the same time and place observes the boiling point of pure water in free air. The first observation determines the pressure in terms of the weight of the mercury column and the second determines it in absolute units. By combining the results the intensity of gravity may be computed.

The International Geodetic Association has for the past ten years operated six or more observatories continuously to determine the variation of latitudes, or the movement of the pole of rotation of the earth. At present eight stations are in operation, two in the southern hemisphere. Three of the stations are in the United States—at Gaithersburg, Md., Cincinnati, O., and Ukiah, Cal. A grant was made to install an additional new instrument of special design at the Gaithersburg observatory. The motion of the pole is now known with great accuracy, its location on any given night for ten years past being known with reference to its mean position within 4 ft. as a rule. Little progress is being made, however, in explaining why the pole moves in this particular way. The observations will be continued for at least three years more.

The longest measurable arc of a meridian on the earth's surface is about 105° long, extending from Cape Colony at the southern end of Africa to the northern limit of Russia in Europe, from latitude 33° south to 70° north. Of this great arc more than one-half has already been measured by triangulation. Of the African part, about one-half has been measured within the past decade and steady progress is being made on that part which lies in Egypt—about 20° in length. The completion of this great arc will be a memorable event in the history of geodesy.

Canada was represented for the first time, at this Conference, by Dr. W. F. King. His report shows that Canada has during the past two years made a very energetic start in precise leveling and in triangulation in Ontario and the provinces farther east, using excellent methods of the highest grade of accuracy.

A CELLULOID COMB FACTORY BURNED in Brooklyn, N. Y., Nov. 8, and nine persons lost their lives in the flames. The fire started on the ground floor in raw material near the elevator shaft and spread with great rapidity. Iron bars across the windows of the second and third floors are held responsible for the loss of life. The building, situated at 152 Columbia St., was originally a three-story tenement. It had been occupied by the comb company for three years.

A PASSENGER TRAIN WAS DERAILED Nov. 6 in Jersey City on the Pennsylvania R. R. Four trainmen were killed and about 20 passengers were injured. The accident occurred on the elevated tracks at the flag-station known as Waldo, near Brunswick St. The passenger train, from Philadelphia, was entering the city at a speed of 15 or 20 mi. per hr. A light locomotive was at the same time backing toward the Jersey City terminal on a parallel track. The locomotive of the Philadelphia train left the rails and sideswiped the other engine, which was completely wrecked. All of the six cars of the train (a smoker, a combination mail and baggage car and four coaches) were derailed and one of them, the smoker, turned over on its side. With one exception, the injured passengers were in the overturned car. The combination baggage car was the only wooden car in the train, and none of the cars were very much damaged. The accident is unofficially ascribed to a defective rail.

FOREST FIRES IN VIRGINIA last week laid waste a large acreage of timber land in the Blue Ridge Mts. A hotel building and 27 cottages were destroyed Nov. 4 at Black Rock Springs, and several other settlements were saved only by the vigorous efforts of the inhabitants.

RAILWAY ACCIDENTS in the United States during the year ending June 30, 1909, according to bulletin No. 32 of the Interstate Commerce Commission, killed 2,791 persons and injured 63,920 others. This is a decrease of 973 killed and 5,009 injured as compared with the figures for the previous year. Bulletin No. 32 covers the quarterly period ending June 30, 1909. During that period, 588 persons were killed and 15,307 were injured—a decrease of 3 in the number killed and an increase of 2,209 injured compared with the corresponding quarter a year ago. Of the 588 killed, only 99 (16.8%) were killed in train accidents.

The number of passengers killed in these three months was 37. Of these, 26 lost their lives in falling from cars while getting on or off, and only three were killed in train accidents. There were 817 collisions and 1,283 derailments in the quarter, of which 100 collisions and 172 derailments affected passenger trains. The total damage to railway property was $1,703,642.

AN AEROPLANE FLIGHT of 144 miles in 4 hrs. 6 min. 25 sec. was made at Mourmelon, France, on Nov. 3, by Henry Farman. This flight was in competition for the 1909 Michelin cup, which was won in 1908 by Wilbur Wright in a two-hour flight, and is the best endurance record yet made.

WIRELESS COMMUNICATION over a distance of 4,720 miles is the record made from the Pacific Mail steamship "Korea" on Nov. 3. The message was sent from the ship, when 2,622 miles west of Honolulu, to San Francisco. The day before a message had been sent when the boat was 4,305 miles distant. This feat is considered remarkable as the ship carried only a 5-KW. plant and an aerial antenna only 100 ft. above the water.

U. S. NAVY DRY DOCK NO. 4, at the Brooklyn Navy-yard has entered upon another phase of its varied existence. Already two successive firms have taken the contract for its construction but each, after many months' labor against the shifting bottoms of the East River, has given up the job. After the last failure it was at first thought that the department would undertake the construction by day labor, but this was decided against and bids were again asked from private companies. Several bids were received, in spite of previous trouble on the work, and the completion of the dock was let to the firm of Holbrook, Cabot & Rollins, of Boston, for $1,390,000. The original appropriation for the dock was $1,500,000, of which only $1,260,000 is now left, so that there was at first some conjecture as to how the government could legally accept a bid above the available appropriation. This difficulty has been adjusted, however—just how, it has not been announced—and the work can now proceed.

THE UNITED STATES RECLAMATION FUND, used in the construction of irrigation works, now amounts to about $60,000,000. This fund is derived from the sale of public lands in 16 arid states and territories. According to a recent statement issued by the Reclamation Service, there had been invested in 30 irrigation projects up to June 30, 1909, about $48,000,000. Against the balance of $12,000,000 available for expenditures up to the close of 1910 there are accrued liabilities of about $2,000,000 for the year 1909, leaving a net balance of some $10,000,000. The Senate Committee is now making a tour of the various irrigation projects being carried out by the U. S. Reclamation Service. It is expected that conclusions drawn from this investigation will have some bearing upon the proposal which has recently been made for a $10,000,000 bond issue. Such an issue would require Congressional authority.

THE U. S. BATTLESHIP "NORTH DAKOTA" passed through some remarkably good speed trials in the week just gone. On Nov. 4 in her builders' trials off the coast of Maine she developed a maximum speed of 22.25 knots and an average of 21.833, both in excess of similar records for any vessel of the battleship class in any navy. In reaching this speed the "North Dakota" developed a maximum horse-power of 35,150. On Nov. 5 on her four-hour endurance run, the battleship made an average speed of 21.51 knots in spite of the fact that at the beginning of the fourth hour, a 7-in. tube in one of the water-tube boilers blew out, so that four of the fourteen boilers were thrown out of commission. Four men were injured by the blow-out, one so severely that he died the next day. On Nov. 6 a 24-hour endurance trial was held,

during which the vessel maintained a speed of 12 knots. On Nov. 7, the 24-hour 19-knot trial was held.

The "North Dakota" is the heaviest battleship in the American Navy, and with the possible exception of the recently-launched British ship "Neptune," is the largest in the world. She is of the so-called "Dreadnought," all-big-gun type, and is equipped with Curtis turbine engines. Her dimensions and armament are as follows:

Length on load water line	510 ft.
Breadth, load water line	85 ft. 2⅝ ins.
Trial displacement, not over	20,000 tons
Mean draft, trial displacement	27 ft.
Total coal bunker capacity	2,300 tons
Coal carried on trial	1,000 tons
Feed water on trial	66 tons

Armament:

Ten 12-in. breech-loading rifles.
Fourteen 5-in. rapid-fire guns.
Four 3-lb. saluting guns.
Four 1-lb. semi-automatic guns.
Two 3-in. field pieces.
Two machine guns, caliber .30.
Two submerged torpedo tubes.

She was built by the Fore River Shipbuilding Co. at an approximate cost of $10,000,000.

A PECULIAR COLLAPSE of a reinforced-concrete wall under construction recently occurred at Los Angeles, Cal., where, in the erection of a reinforced-concrete building, the side wall of an adjoining brick building used as the outside form for the new concrete wall, was forced over by the pressure from the green concrete, resulting in the collapse of the old building. It is stated that not only was the brickwork of a decidedly poor nature, but that the old building was so arranged as to give a minimum of bracing for the wall used as a form. This wall was a long one, forming one wall of a hall for its full length, and the roof beams ran in the same direction so that the wall was without support from partition walls or beams. In addition there was a light well opposite the point of break, thus further reducing the transverse stiffness of the old building.

A HIGH RECORD IN MASONRY LAYING was accomplished last month on the Ashokan Reservoir of the new water supply system for the city of New York. During the month ending Oct. 20, 1909, there was placed on the Olive Bridge Dam, 33,142 cu. yds. of cyclopean masonry and 2,117 cu. yds. of concrete blocks, a total of 35,259 cu. yds. The contract is held by the joint firm of MacArthur Bros. Co. and Winston & Co., and the General Superintendent is Mr. M. J. Look.

DIVIDING CONTRACTS FOR THE BALTIMORE, MD., sewerage system and "extensive advertising have effected a large saving," according to an official report of Mr. Calvin W. Hendrick, M. Am. Soc. C. E., Chief Engineer of the Baltimore Sewerage Commission. Mr. Hendrick states that the $6,000,000 of contracts already let

have been secured by responsible contractors from Baltimore, New York, Boston, Philadelphia, Chicago, Washington, Pittsburg, Bethlehem, Pa., Lancaster, Pa., Cleveland, Ohio, Logansport, Ind., Crafton, Pa., and Esmont, Va.

A FIRE TEST ON REINFORCED-CONCRETE GRAIN Tanks.—In the October, 1909, issue of the "Quarterly of the National Fire Protection Association," there is a report of a severe fire which occurred on Sept. 16, 1909, in a flour mill at Portland, Ore., through which four reinforced-concrete grain tanks passed with great credit. The plant contained among other structures two timber buildings, one five stories and the other three stories high spaced about 60 ft. apart and on the space between were built the four tanks, joined together and each some 80 ft. high and about 20 ft. in diameter. A fire started in the five-story building, completely destroyed it, and then passed over the tanks to the adjoining buildings which were also completely destroyed. Although the flames raged all around the concrete tanks they were not damaged to any extent. They were empty at the time so the transfer of heat to enclosed grain under such conditions cannot be judged. No serious cracks have been detected in the tanks and there is only a slight spalling to be noticed on the outside surface.

A NEW RAILWAY STATION AT BALTIMORE, MD., on the site of the present Charles St. Union Station, is to be built by the Northern Central Ry. Co., one of the subsidiary roads to the Pennsylvania R. R. This station is used by the Pennsylvania's New York to Washington service, the Western Maryland R. R. and the Northern Central. The present station and sheds will be removed.

According to reports from the company

the new station will be 60 ft. wide and 275 ft. long. It will be of classical design and will be built of stone, terra cotta, brick and ornamental metals. The interior will be finished in marble, plaster, hard wood and leaded glass. The structure will be fireproof and supported by a steel frame. It will consist of the station proper and two upper floors for the offices of the company. The main waiting room, 64 ft. wide, 95 ft. long, and 55 ft. high, will occupy the center of the street floor. Adjoining it will be ticket offices, telegraph and telephone offices, news stand, retiring rooms for men and women, lunch room, dining room, parcel and baggage rooms. The entrance to the main waiting room will be reached by walks and driveways from St. Paul and Charles Sts., and the floor will be slightly above the level of Charles St. The waiting room will be lighted by ornamental leaded glass sashes placed in the ceiling. A covered lobby 350 ft. long and 28 ft. wide will extend along the track side of the station and connect with Charles St. bridge, allowing passengers to go to and from trains without entering the building proper. An enclosed lobby 50 ft. in width will extend across the seven passenger tracks, which will be 18 ft. below the main floor of the station. This lobby will open into the main waiting room of the station. Eight stairways will lead to the train platforms, which will be 20 ft. wide and from 600 to 1,100 ft. long; the latter will accommodate a train of 15 cars. The platforms will be protected with ornamental steel shelters or canopies.

The new station is the design of Mr. Kenneth M. Murchison, who designed the Hoboken and the Scranton stations for the Delaware, Lackawanna & Western R. R.

COST-KEEPING CARDS are being issued by the U. S. Reclamation Service for the benefit of its engineers. These cards show in some detail the cost of a considerable variety of engineering work carried out in connection with various irrigation projects. The cards are reproduced by photolithography from typewritten sheets. They are 6½ × 4¼ ins. in size. The tabular cost data are supplemented by sufficient notes to give a general idea of the character and governing conditions of the work. The bunch of 64 cards is secured by brass fasteners and makes a pack only ⅝-in. in thickness. Among the cards we find costs of siphons, telephone lines, canals, laterals and ditches, bridge abutments, steel highway bridges, flumes and sluiceways, pile bridges and embankments. Contractors' costs, contractors' earnings, and cost to the United States, are given in totals and in unit figures. In some instances the contractor's cost is itemized under interest, preparatory, depreciation, executive, labor, material and supplies.

Personals.

Mr. H. J. Slifer, M. Am. Soc. C. E., General Manager and Assistant to the President of the Panama R. R., has resigned to become General Manager of the Chicago, Great Western Ry., with headquarters at Chicago, Ill.

Mr. D. D. Colvin, Assoc. M. Am. Soc. C. E., District Engineer of the National Rys. of Mexico at Guadalajara, has been appointed Chief Engineer of the Pan-American R. R.

Mr. C. L. Nicholas, Division Superintendent of the Northern Pacific Ry. at Livingston, Mont., has been made General Superintendent at Livingston to succeed Mr. G. A. Goodell.

Mr. W. H. Strachan has resigned as Superintendent of the Minnesota & International Ry. to become Assistant Division Superintendent of the Northern Pacific Ry. at Duluth, Minn.

Mr. L. C. Fritch, M. Am. Soc. C. E., Consulting Engineer of the Illinois Central Ry. (and formerly Assistant to the President), has been appointed Chief Engineer of the Chicago Great Western Ry. in charge of the extensive work of improvement which has been undertaken by the reorganized company.

Mr. W. A. Whitney, formerly Division Superintendent of the Union Pacific R. R., at Ogden, Utah, has been transferred to the San Francisco division with headquarters at Oakland, Cal. Mr. William Jeffers, formerly Assistant Division Superintendent at Ogden, has been appointed to succeed Mr. Whitney.

An engineering committee on electrification of railway terminals has been appointed by the Chicago Association of Commerce, and is composed of the following members: John M. Ewen (Chairman), A. Bement, W. L. Abbott, B. J. Arnold, Paul P. Bird (Smoke Inspector), Prof. W. F. M. Goss, and Prof. C. E. Merriam.

Mr. Joseph Ripley, M. Am. Soc. C. E., Advisory Engineer to the Department of Public Works, New York State, has been appointed a member of the advisory board of consulting engineers for the New York Barge Canal to succeed Mr. William A. Brackenridge, who is now Vice-President and General Manager of the Southern California Edison Co.

Mr. Trygve Jensen, a graduate of the Department of Electrical Engineering of the University of Illinois, has been awarded the prize offered by the Edison Medal Committee of the American Institute of Electrical Engineers for the best thesis presented in competition. The title of his thesis is "The Operation of a 100,000-volt Transformer." The prize consists of a diploma and a cash award of $150.

Mr. E. H. Barrett, Superintendent of the Missoula division of the Chicago, Milwaukee & Puget Sound Ry., has been placed in charge of the Mussel Shell, Rocky Mountain and Missoula divisions, with headquarters at Butte, Mont. He is succeeded at Missoula by Mr. C. H. Marshall, formerly Superintendent of the Columbia division. Mr. A. H. Moll, formerly Trainmaster of that division, has been made Superintendent to succeed Mr. Marshall.

Mr. Allan A. Robbins, M. Am. Soc. C. E., and Mr. John W. Ripley, M. Am. Soc. C. E., have opened an office as engineers and contractors at 50 Church St., New York City, under the name of the Robbins-Ripley Co. Mr. Ripley, a graduate of Cornell University, for the past nine years has been Chief Engineer of the structural department of John Monks & Son and is still retained by that company as Consulting Engineer on extensive work in the South. He also retains his interest in the Monks-Ripley Pile Co. Mr. Robbins was formerly Principal Assistant Engineer on the Belmont Tunnel.

Dr. Ernst J. Berg, M. Am. Inst. E. E., Consulting Engineer of the General Electric Co., Schenectady, N. Y., has become Professor of electrical engineering at the University of Illinois, in charge of the department. Dr. Berg was born in Sweden in 1871 and graduated at the Royal Polytechnical Institute, Stockholm, in 1892, in mechanical engineering. In the following year he came to the United States and has been associated with the General Electric Co. for the past 17 years. Dr. Berg succeeds Mr. Morgan Brooks, M. Am. Inst. E. E., now absent on leave, as head of the department of electrical engineering, but it is announced that at the expiration of his leave Mr. Brooks will continue as a professor in the department.

Engineering Societies.

COMING MEETINGS.

NATIONAL MUNICIPAL LEAGUE.
Nov. 15-19. Annual meeting at Cincinnati, Ohio. Secy., Clinton R. Woodruff, Philadelphia, Pa.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS.
Nov. 16. Annual meeting at Washington, D. C. Secy., Martin S. Decker, Albany, N. Y.

AMERICAN RAILWAY ASSOCIATION.
Nov. 17. Annual meeting at Washington, D. C. Secy., W. F. Allen, 24 Park Place, N. Y.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.
Nov. 18-19. Annual meeting at New York City. Secy., W. J. Baxter, 29 West 39th St., New York City.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION.
Dec. 1-3. Annual convention at Milwaukee, Wis. Secy., James C. Monaghan, 20 West 44th St., New York City.

NEW JERSEY SANITARY ASSOCIATION.
Dec. 3-4. Annual meeting at Laurel-in-the-Pines, Lakewood, N. J. Secy., J. A. Exton, 75 Beech St., Arlington, N. J.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 6. Annual meeting in New York City. Secy., Wm. H. Ross, 154 Nassau St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 7-10. Annual meeting at New York City. Secy., C. W. Rice, 29 West 39th St., New York City.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.
Dec. 8-10. Annual meeting at Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.
Dec. 14-15. Annual meeting at New York City. Secy., Percy H. Wilson, Land Title Bldg., Philadelphia, Pa.

AMERICAN INSTITUTE OF ARCHITECTS.
Dec. 14-16. Annual convention at Washington, D. C. Secy., Glenn Brown, The Octagon, Washington, D. C.

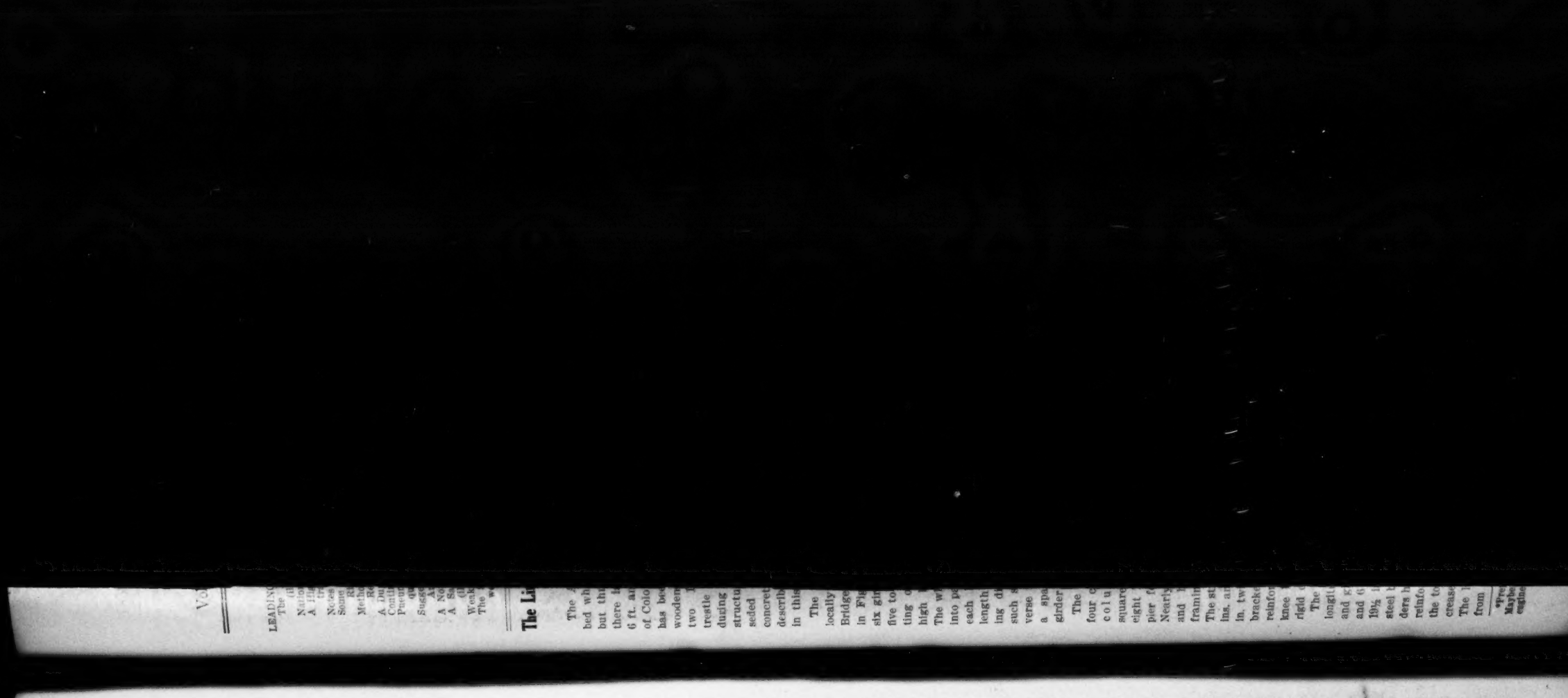
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 27. Annual meeting at Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.
Dec. 28-29. Annual meeting at Ames, Iowa. Secy., L. W. Chase, University of Nebraska, Lincoln, Neb.

MONTANA SOCIETY OF ENGINEERS.
Jan. 6-8. Annual meeting at Butte, Mont. Secy., Clinton H. Moore, Butte, Mont.

MICHIGAN ENGINEERING SOCIETY.
Jan. 12-14. Annual meeting at Lansing, Mich. Secy., Alba L. Holmes, 574 Wealthy Ave., Grand Rapids, Mich.

INDIANA ENGINEERING SOCIETY.
Jan. 14-16. Annual convention at Indianapolis, Ind. Secy., Chas. Brossmann, Union Trust Bldg., Indianapolis, Ind.

OHIO SOCIETY OF MECHANICAL, ELECTRICAL AND STEAM ENGINEERS.—At the meeting at Lima, Ohio, Nov. 19-20, papers will be presented as follows: Nov. 19, "Power Costs for Factories," (presidential address), F. W. Ballard, Cleveland, Ohio; "The New Laboratory of the Department of Mechanical Engineering at the Ohio State University," E. A. Hitchcock, Columbus, Ohio. Nov. 20, "The Darling Oil Gas Producer," A. B. Davis, Indianapolis, Ind.; "Notes on Coal and Ash Handling Equipment," David Gaehr, Cleveland, Ohio.

NEW ENGLAND WATER WORKS ASSOCIATION.—Nominations for officers to be voted upon at the annual meeting in January, 1910, have been submitted by the nominating committee as follows: For President, George A. King, Taunton, Mass.; for Vice-Presidents, Allen Hazen, New York City; Ermon M. Peck, Hartford, Conn., M. F. Collins, Lawrence, Mass., Leonard Metcalf, Boston, Mass., I. S. Wood, Providence, R. I., F. A. McInnes, Boston, Mass.; for Secretary, Willard Kent, Narragansett Pier, R. I.; for Treasurer, Lewis M. Bancroft, Reading, Mass.; for Editor, Richard K. Hale, Boston, Mass.; for Advertising Agent, R. J. Thomas, Lowell, Mass.